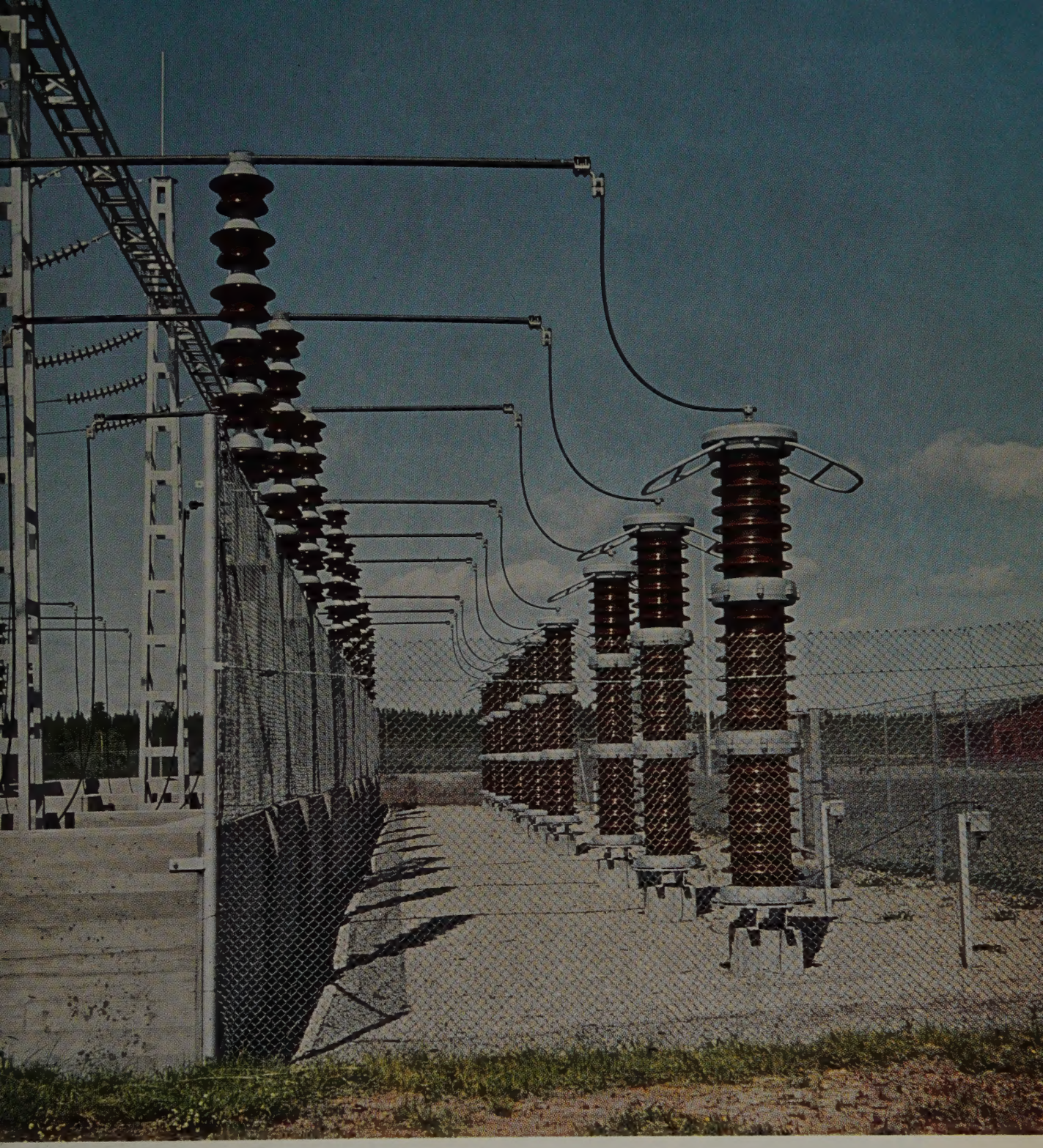

Lightning arresters with a rated voltage of 240 kV in the Gulsele Power-station. (F 305)

ASEA JOURNAL 1961

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3

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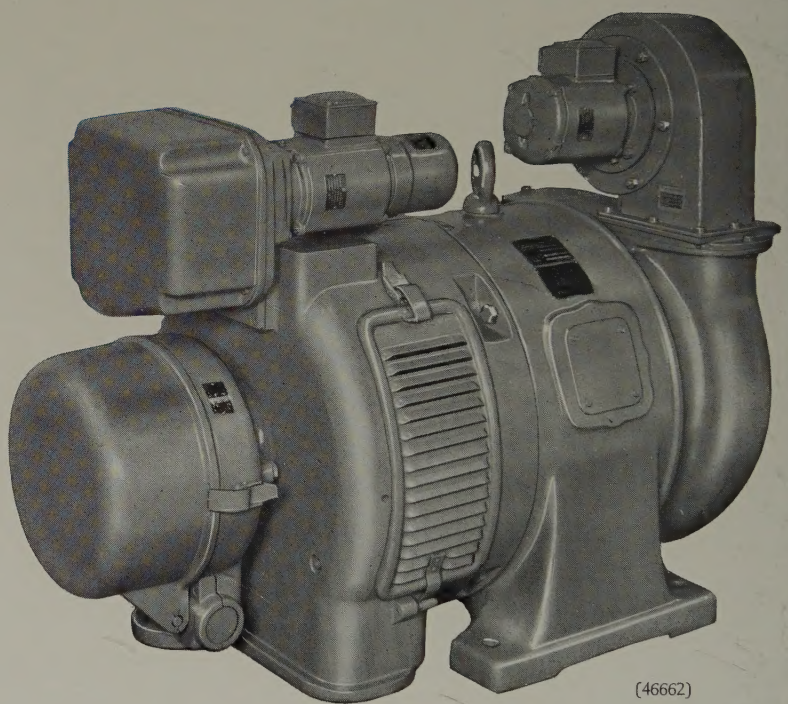

(46662)

Use the ASEA commutator motor with continuous speed regulation for continuous processes

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THE BACK-UP CIRCUIT-BREAKERS, HIGH-SPEED MAKING SWITCHES AND ISOLATORS IN THE ASEA HIGH-POWER LABORATORY AT LUDVIKA

Arne Strindemark, Switchgear Department, Ludvika

U.D.C. 621.317.2:621.316.54
Asea Reg. 54

The article describes the back-up circuit-breakers, high-speed making switches and isolators specially designed for the new Asea High-power Laboratory at Ludvika. Particular attention is paid to the back-up circuit-breakers since they are representative of a new principle in the field of air-blast circuit-breakers.

The very comprehensive equipment for the new Asea High-power Laboratory at Ludvika [see Asea Journal 33 (1960):9, pp. 131–141] includes, amongst other things, back-up circuit-breakers, high-speed making switches, and isolators, all of which items are subject to certain very special demands. The back-up circuit-breakers and the high-speed making switches in particular, and the isolators to a rather lesser extent, have therefore been specially designed for installations of this kind.

BACK-UP CIRCUIT-BREAKERS

The basic design

In earlier types of air-blast circuit-breaker, the arc-extinction chambers are only placed under pressure during the actual breaking operation. This is usually arranged by means of compressed air stored in a container in the lower part of the circuit-breaker, and which is allowed to enter the arc-extinction chamber by way of a pneumatic valve and air ducts of varying length. The compressed air separates the contacts and provides the pneumatic blast required for extinguishing the arc. As a rule, circuit-breakers of this kind are fitted with an isolator connected in series with the power break, and which is opened after the arc is extinguished and is also used for closing the circuit-breaker.

The back-up circuit-breakers (type HTHZ) for the High-power Laboratory are representative of a new air-blast circuit-breaker principle (see Figs. 1 and 2). It is true that they have, in this case, been specially designed bearing in mind laboratory service, but the principle is also generally applicable to standard circuit-breakers for all voltages in use to-day.

The principle implies, amongst other things, a new arrangement of the pneumatic system. The contacts of the break are enclosed in a pressure chamber (Fig. 1) insulated from earth. The chamber is kept under pressure both when the circuit-breaker is closed and when it is open. The exhaust valve is on the "downstream side" of the break and its vent projects into the ambient air (Fig. 2). When it is opened on breaking, a supply of air adequate for arc extinction flows out of the pressure chamber via a nozzle-shaped moving contact.

The exhaust valve is only open during the actual breaking operation itself, and recloses when the moving contact has reached its open end position. Insulation between the contacts in the open position is provided by the compressed air. Further, because the exhaust valve

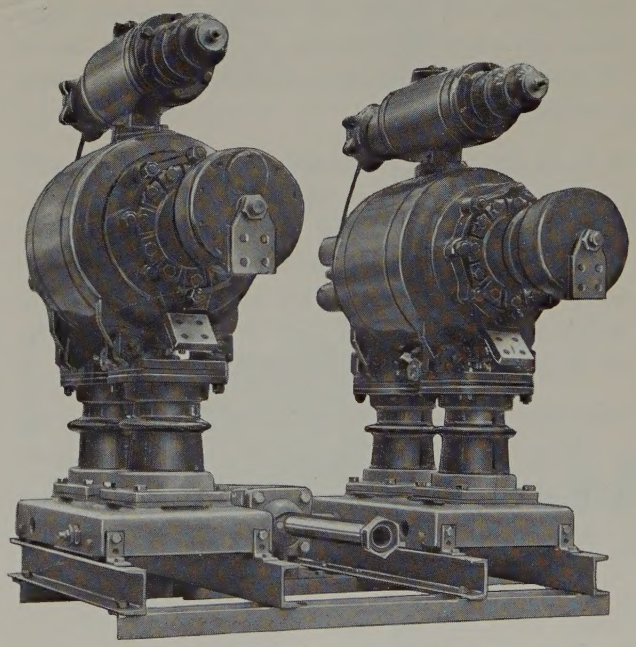


Fig. 1. Two poles of the new back-up circuit-breaker for the High-power Laboratory at Ludvika. The power break is located in the larger container and the resistor break in the smaller one. (48962)

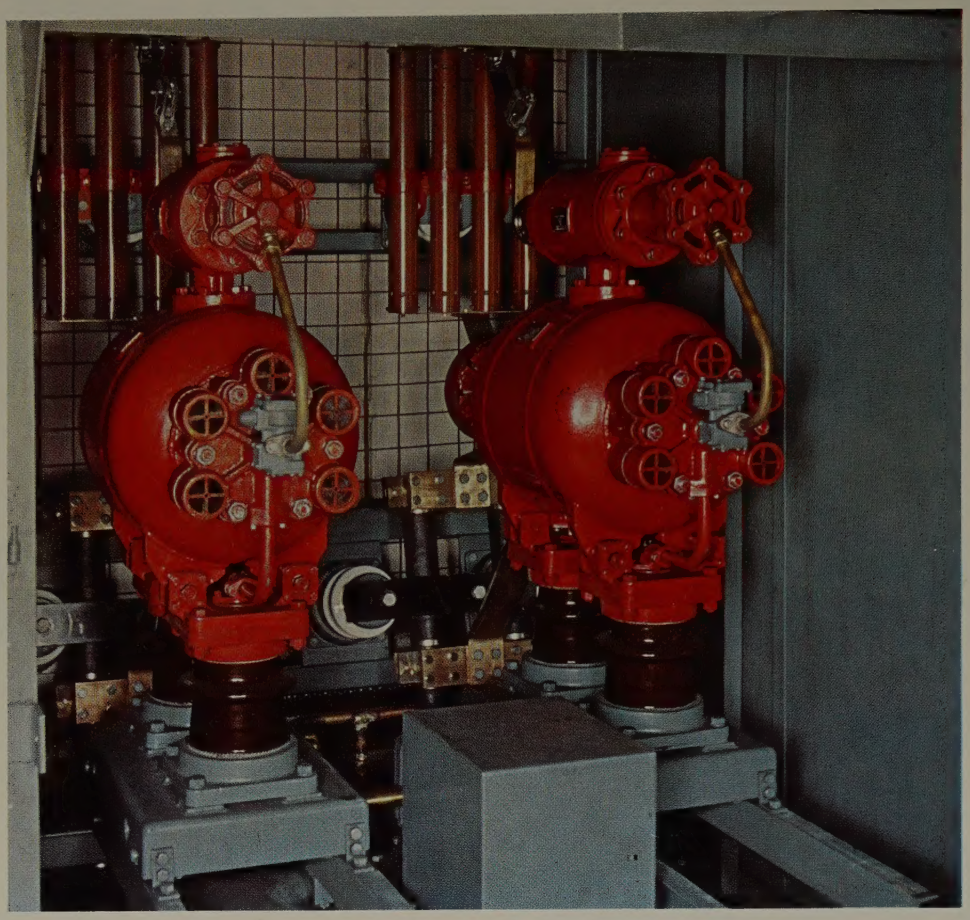


Fig. 2. The back-up circu
breaker in place in t
High-power Laboratory.
The five exhaust openi
for the power breaks
provided with coolers. T
damping resistors are
mounted on the wall in t
background. (F 558)

is closed during the closing operation of the circuit-breaker no air is then consumed and the contacts close in an atmosphere of compressed air.

For opening and closing and closing operations, rapid filling and emptying sequences in the ducts are carried out only in a separate duct system used for operation purposes alone.

If, as in this case, the circuit-breaker is provided with a resistor connected in parallel with the power break, a special break is required for breaking the resistor current after the main arc has been extinguished. However, the resistor current is low and therefore the demands made on this extra break are relatively small as far as breaking capacity is concerned.

The main advantages of this type of circuit-breaker are as follows:

1. Since there is compressed air at full pressure around the contacts at the very moment they are separated, the arcing time is short and there is little contact burning.

2. Since no rapid filling of the breaking chamber with compressed air is required in conjunction with breaking, the pressure oscillations and the turbulence which arise in the case of filling of this kind and which have an unfavourable effect on the breaki capacity are avoided.

3. Since the exhaust valve is only open during breakin the consumption of compressed air is low.

4. The compressed air acts as insulation between t contacts when they are open. Its high dielect strength also makes is possible to do without integ series isolators with their usually complicated op ating gear, even when the contact travel is relative short.

5. Closing takes place in an atmosphere of compress air for which reason pre-arcing is suppressed and high making capacity can be achieved.

6. The moving parts of the interruptor (contact a exhaust valve) can be combined into a compact un thus simplifying inspection and maintenance.

Design

The design of the back-up circuit-breaker can be se from Fig. 3. A bushing 1 in the one end of the pressu chamber carries the fixed contact 2 and insulates it a its leads against contact with the conducting walls the pressure chamber. The fixed contact consists of number of spring segments around a central fixed plu The moving contact 3, the interior of which makes up part of the exhaust channel, is combined with the

haust valve 5 and its operating piston 7 to form a single unit. The current path runs along the walls of the pressure chamber, and the current is transmitted to it from the moving contact with the aid of sliding contacts.

The operating cylinder of the exhaust valve can be linked with the compressed-air supply system by means of a duct 9 for the controlling air and a control valve (the latter common to two poles), while the pressure chamber is always linked with this system without any intermediate valves.

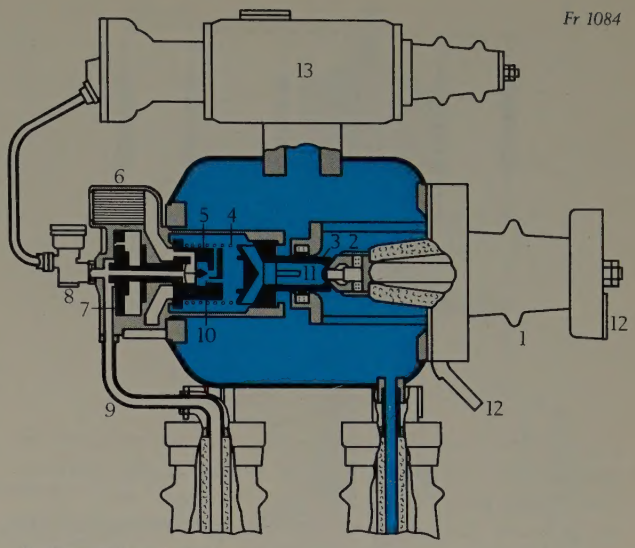
Separately mounted resistors connected in parallel with the main break are used for damping the rate of rise of the restriking voltage (see Fig. 2).

The resistor breaks 13 are, on the whole, a reduced version of the main breaks and their pressure chamber is located above that of the main break. The controlling air is obtained from the operating cylinder for the main breaks via a time-lag valve 8, which provides the necessary time interval between the moment of opening of the main breaks and that of the resistor breaks.

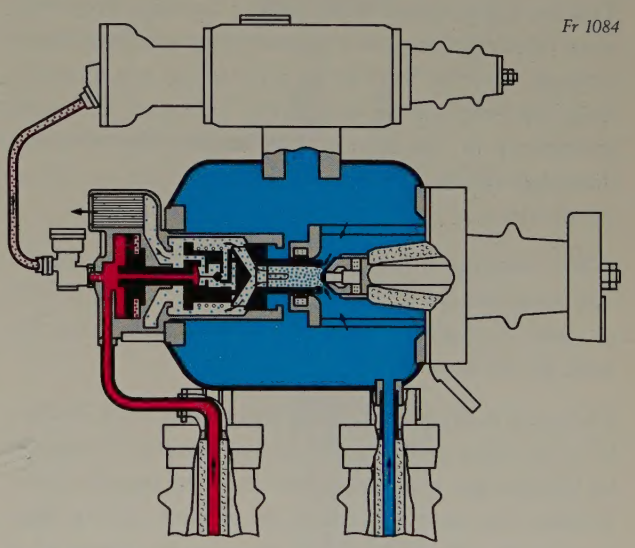
Mode of operation

The closed position (Fig. 3 a). In the closed position, the closing spring 4 forces the nozzle contact against the segments of the fixed contact. The pressure chamber is closed by means of the exhaust valve. The duct for the controlling air is at atmospheric pressure.

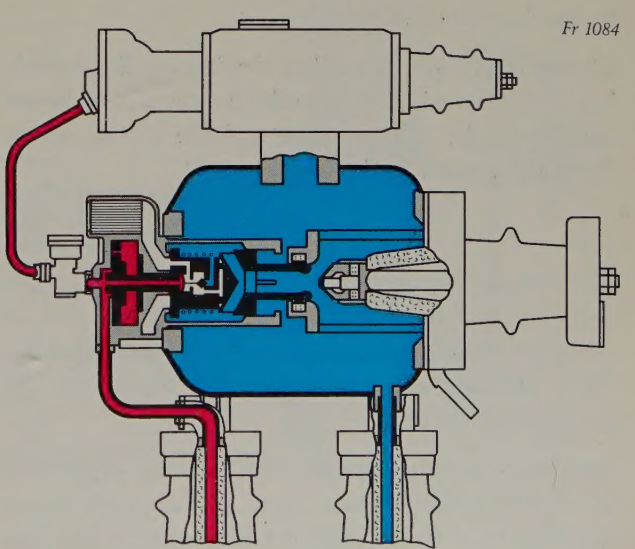
Breaking (Figs. 3 b and c). When a breaking impulse is received, the valve for the controlling air is opened and the operating cylinder of the exhaust valve is filled with compressed air. The exhaust valve then opens and links the pressure chamber with the ambient air. Because of the drop in pressure, the moving contact opens and the arc which is formed is centered between the point of the fixed contact and an arcing contact 11. The contact movement continues, to begin with, until the rear part of the contact strikes a sealing surface on the exhaust valve. In this position, the quenching position, the contact remains stationary for a few milliseconds. When it then continues its movement, it forces the exhaust valve back into the closed position. This is made possible by the fact that, after a certain delay, the difference in pressure between the two sides of the piston of the exhaust valve has been equalised.



a) Circuit-breaker closed



b) Extinguishing position



c) Circuit-breaker open

Fig. 3. The operation of the back-up circuit-breaker during the operating cycle.

. Bushing
. Fixed contact
. Moving contact
. Closing spring
. Exhaust valve
. Cooler
. Operating piston for the exhaust valve
8. Time-lag valve
9. Ducts for the controlling air
10. Auxiliary valve
11. Arcing contact
12. Connections
13. Resistor break

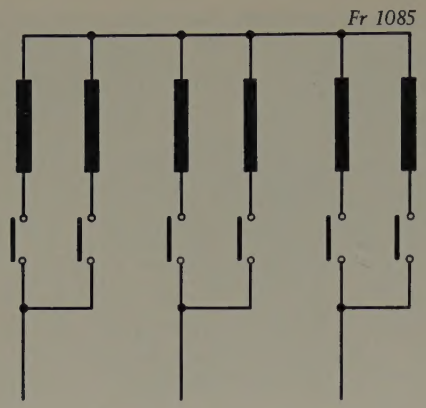


Fig. 4. The back-up circuit-breaker is connected with one pole in series with each winding section of the generator. The voltage per pole is 7.5 kV for generator 1 and 3.75 kV for generator 2. Generator 1 in the connection shown above (Y-parallel) thus provides the main voltage of 13 kV.

Thus, the contact movement takes place in two stages. This has a favourable effect on the breaking properties since relatively long total contact travel can be adopted without the risk of the arcs becoming unnecessarily long. The length of the first part of the travel movement corresponds to "the optimum arc length", that is to say, the length of arc at which the best quenching conditions are obtained.

While breaking is taking place in the main breaks, the operating cylinder of the resistor break is supplied with air, and its contacts open a few half-cycles after the main breaks have done so.

The open position (Fig. 3 c). When the circuit-breaker is in the open position, the moving contact is retained by the pressure in the chamber, since the separate space between the contact part and the exhaust valve is kept in contact with atmospheric pressure by means of a membrane-controlled auxiliary valve 10. The contact remains in this position as long as pressure is maintained in the duct for the controlling air.

Making (Fig. 3 a). On making, the duct for the controlling air is emptied whereupon the contact part no longer adheres to the exhaust valve and the closing spring forces the contact to close.

Data

The back-up circuit-breaker consists of six poles per generator and these are connected with one pole in series with each winding section in the generator (Fig. 4). Thus, breaking requirements do not depend on the generator connection.

With two units per phase, the breaking capacity is 2,700 MVA (three-phase breaking capacity), corresponding to a symmetrical breaking current per unit of about 60 kA at 13 kV. The asymmetrical breaking capacity is 25 per cent greater. The opening time about 40 ms and the make-time about 150 ms. T consumption of air for a breaking operation is o about 550 l (20 cu.ft) of air at atmospheric pressu per pole at the rated pressure of 15 atmospheres gau

So far, the circuit-breakers have proved to be m satisfactory in service. Even in the case of the highe breaking current, contact burning is very slight, and th must be regarded as being particularly advantageous the case of a circuit-breaker of this kind. This has be achieved by, amongst other things, providing the co tacts with a cladding of arc-resistant metal.

HIGH-SPEED MAKING SWITCHES

The installation is provided with two kinds of hig speed making switch, that is, type HZT for the hig power equipment and type HZA for the high-curre equipment.

High-speed making switch type HZT

The task of these high-speed making switches (Fig. 5 is to close the test circuits and thus initiate short ci cuiting, for example, in the case of breaking tests o

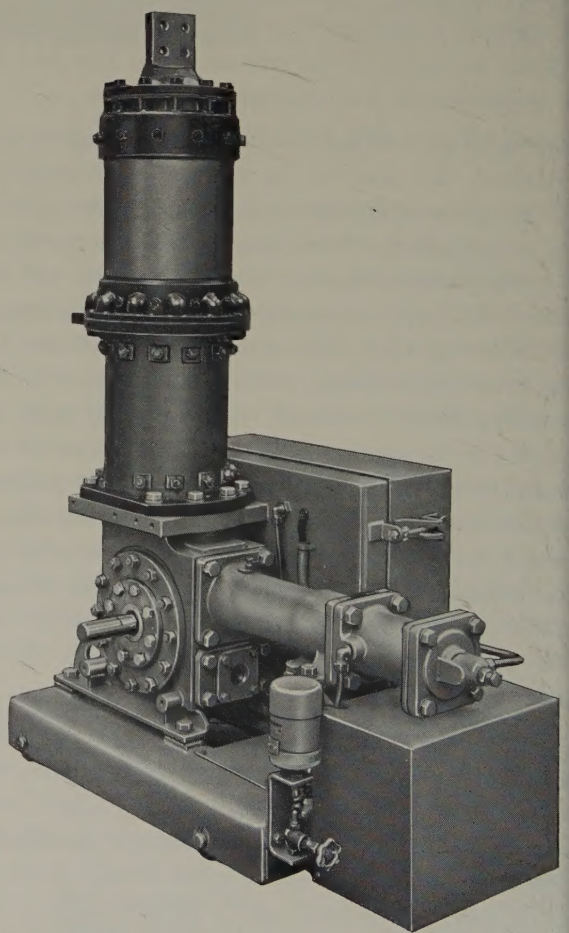
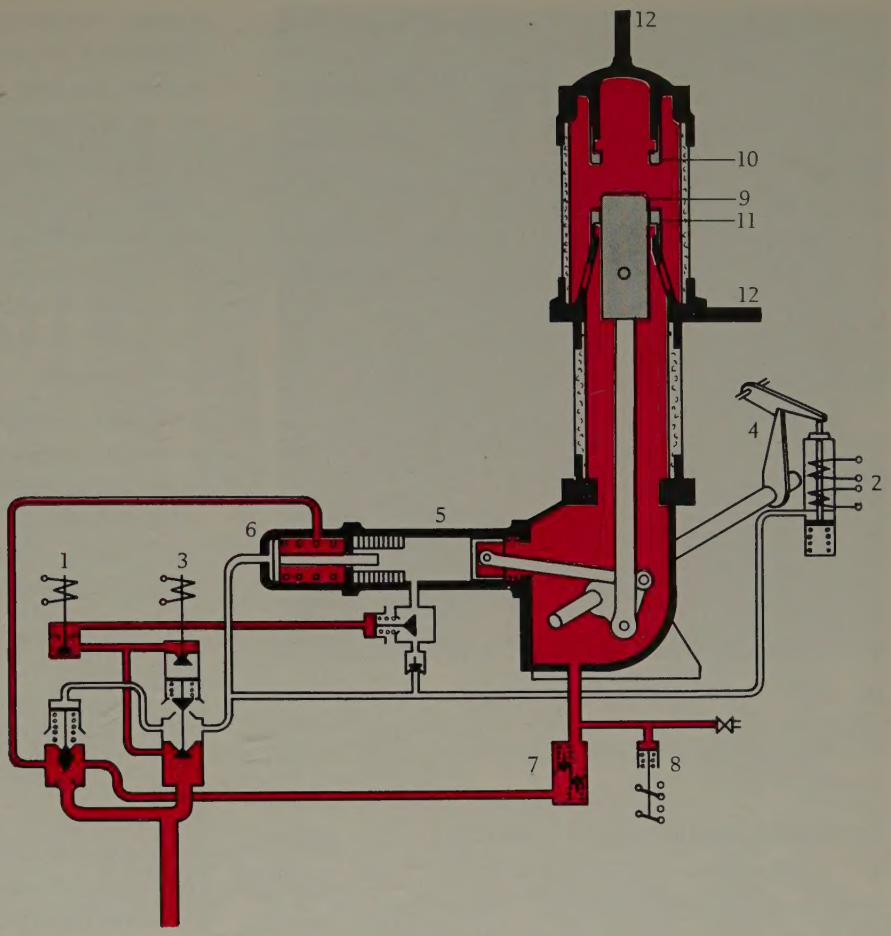


Fig. 5. High-speed making switch for the high-power equi ment. Making time 30 ms with an accuracy of better tha ±5 electrical degrees. (48960)

ig. 6. High-speed making witch for the high-power nstallation. Operation on eceipt of making and reaking impulses.

1. Making electromagnet
2. High-speed electro-magnet for releasing the making latch
3. Breaking electromagnet
4. Latch
5. Main operating gear
6. Auxiliary operating gear
7. Valves
8. Low-pressure blocking device
9. Moving contact
0. Fixed contact
1. Sliding contact
2. Connections

a) Closing



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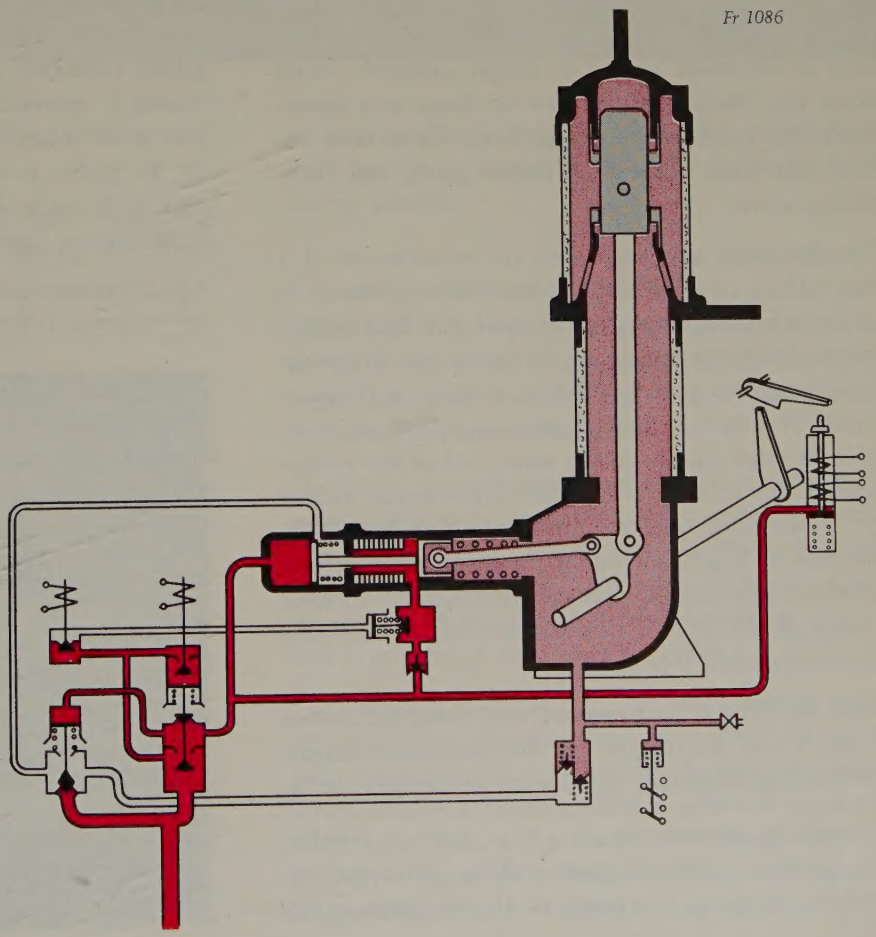
b) Opening



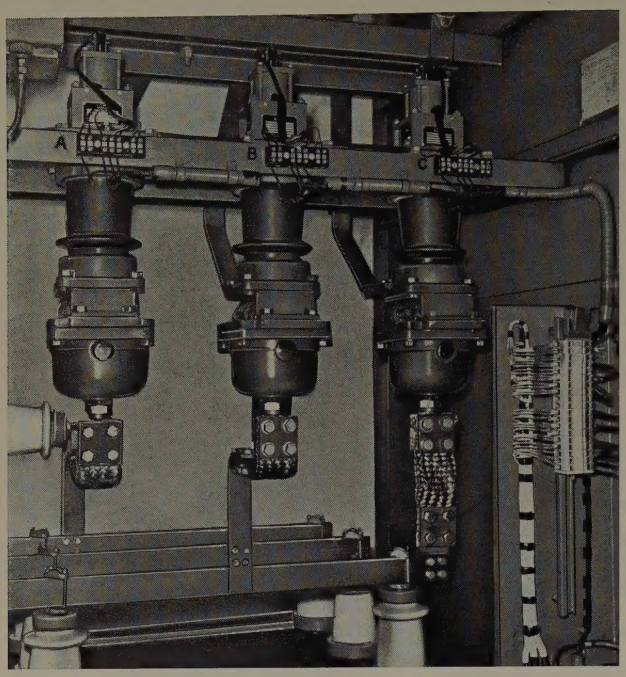


Fig. 7. High-speed making switch for the high-current installation. Making time 7.5 ms with an accuracy of better than ± 5 electrical degrees. (54499)

high-voltage circuit-breakers. This means they must have a high making capacity, but that no demands are made on the breaking capacity since the circuits are always dead when the high-speed making switches are opened.

Since synchronised closing is usually adopted, which means that the test circuit must be closed at a certain determined point on the voltage wave, the error in the make-time must not exceed certain given, and fairly narrow, limits.

The difficulties associated with the achievement of a high making capacity with a contact device, that is to say, high making current when there is a high voltage before closing, are mainly due to two causes. When the contacts approach each other on making, a flashover occurs at a certain contact position, which depends, amongst other things, on the magnitude of the voltage between the contacts. This leads to pre-arcing, and an arc of this kind can, in spite of the fact that it diminishes in length on closing, be sufficient in an unsuitable contact device to bring about such considerable heating of the contact material that the contacts weld themselves when they meet.

After the contacts have met and thus closed the current circuit, it may also happen that they are separated again by bouncing, which may also give rise to damaging arcing.

In order to suppress the pre-arcs as much as possible, the contacts in the high-speed making switch are surrounded by air at a pressure of 15 atm gauge during closing. Because of the high dielectric strength of th compressed air, flashover does not take place until th contacts are very close to each other, and the energy o the arc is therefore correspondingly low.

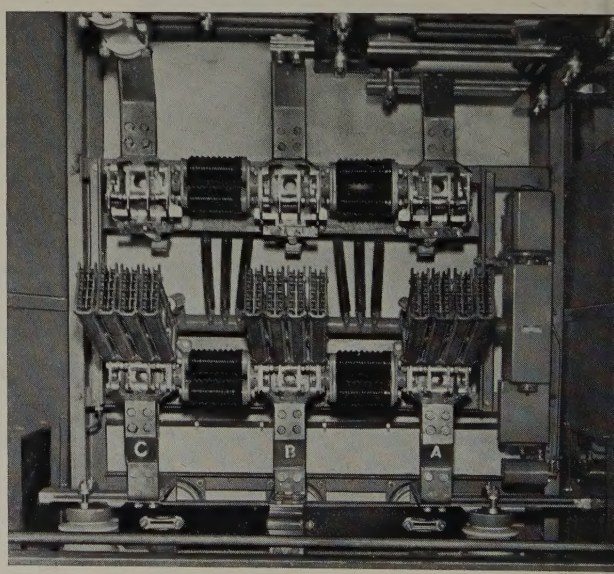
In order to prevent bounce and to achieve high peak current strength, the contacts are of plug-and-socke type in which the very robust plug (diameter 100 mm has a long contact path inside the socket. The latte as is the case with the sliding contacts for transmittin the current to the plug, consists of a large number o contact fingers.

Tests and experience in service have shown that th design, in conjunction with the use of arc-resistant su faces on the contacts, has very satisfactory propertie when closing against high currents. At 300 kA (pea value) and a voltage of 15 kV (r.m.s. value), contac burning is very slight, and there is no welding.

These high-speed making switches have been in use a the laboratory for over two years and about 12,000 clos ing operations have been carried out with them agains short-circuit currents of varying size. It has not bee necessary to change the contacts during this period.

The high-speed making switches are operated by mean of compressed air. In order to prevent any lack o precision in filling the ducts and cylinders, etc. of th operating system from influencing the make-time, clos ing takes place in two stages. During the first stage, th space on the one side of the operating cylinder is com pletely exhausted, and during the time required for thi closing is prevented by means of a mechanical latch The latter is not released until full operating pressur on the piston is obtained. With this device, a make time of 30 ms is obtained and the accuracy is ± 5 elec trical degrees (approximately ± 0.28 ms).

Fig. 8. Isolator rated at 15 kV and 6,000 A, with a peak current strength of 400 kA. (54500)



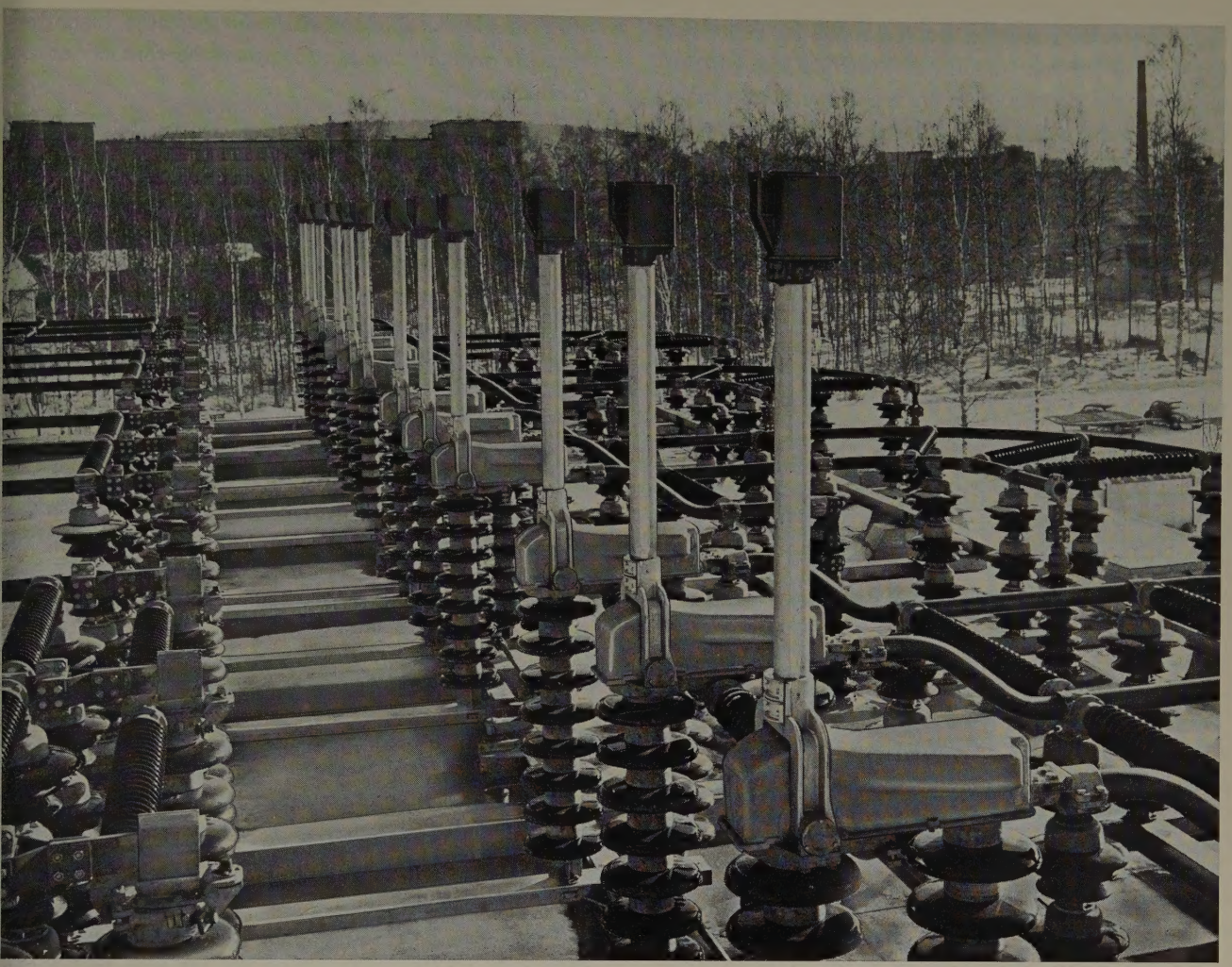


Fig. 9. Isolators rated at 120 kV, 2,000 A, with a peak-current strength of 300 kA. (54201)

The opening of the contacts, on the other hand, takes place in one movement since there are no special demands on the speed of opening or on the opening time.

The high-speed making switch operates in the following way:

Closing (Fig. 6 a). When closing, an impulse is transmitted to the coil 1, whereupon the operating cylinder 5 is exhausted and the moving contact attempts to close, being actuated by the pressure in the pressure chamber. The movement is prevented by the latch 4 which is actuated by the high-speed coil 2. The latch is not released and the contact does not close until this coil becomes live. If the pressure of the compressed air is not sufficiently high, closing is prevented by a low-pressure blocking device.

Opening (Fig. 6 b). Opening impulses are supplied to the coil 3 whereupon the cylinder 5 is filled with compressed air and the pressure in the pole is reduced with the aid of the valves 7. In order to ensure that operation definitely takes place, the cylinder is also actuated by an extra operating device 6. When the contact movement has been completed, the latch 4 returns to the locking position.

High-speed making switch type HZA

In addition to the large high-speed making switches described above, which are used in the high-power equipment, there is also a smaller type (Fig. 7) which is used in the high-current installation.

The lower demands made on the latter in so far as the making capacity is concerned, made possible a considerably simpler design. In spite of its simplicity, this high-speed making switch has extremely satisfactory properties, that is, relatively high making capacity in conjunction with extreme rapidity of operation.

The contacts, which in this high-speed making switch are also of plug-and-socket-type, close in oil. The moving contact is kept in the open position by an electromagnet which acts on an armature linked with the contact by means of an insulated pull-rod. The making movement is brought about by a spring when the electromagnet releases its grip on receiving a making impulse.

Since the total stroke in this case can be kept short (only about 7.5 mm (0.3 in.) of which 2.5 mm (0.1 in.) make up the contact path in the socket), the make-time is as short as 7.5 ms. The spread in time is well within ± 5 electrical degrees.

The moving contact is reset in the open position by means of compressed air.

This high-speed making switch has a rated voltage of 10 kV and a making capacity of 50 kA (peak value) at this voltage.

ISOLATORS

Most of the isolators included in the installation are used for the connecting up of various types of test circuit. All are motor-operated and remotely controlled. The main requirements made on these isolators is that they should be able to withstand repeated high peal currents without damage to either the contacts or th mechanism.

On the generator side, use is made of a standard isolato (type NDD 15/6,000) with a rated voltage of 15 kV intended for a service current of 6,000 A, see Fig. 8 It has, however, been modified in so far as porcelai stays have been mounted between the poles, thus ensur ing good stability when dealing with high currents These isolators will withstand a peak current of 400 kA and a short-time current of 130 kA for 2 seconds.

On the high-voltage side of the transformers, use i made of an isolator rated at 120 kV, 2,000 A, whic has been specially designed for the laboratory. It has peak-current strength of 300 kA and will withstand short-time current of 100 kA for 2 seconds (Fig. 9)

OVER-VOLTAGE PROTECTION IN LOW-VOLTAGE NETWORKS

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U.D.C 621.3.015.3:621.316.93
Asea Reg. 5680, 734

After a brief review of the various kinds of over-voltage which can arise in low-voltage networks, the protection which lightning arresters can offer is dealt with. A surge-generating device for testing the surge strength of low-voltage installations is described.

Comprehensive knowledge of the over-voltages which can arise in high-voltage installations has been available for many years. In most countries, lightning arresters are part of the standard equipment of installations, and the insulation is selected on the basis of the measure of protection which the lightning arresters provide.

Low-voltage networks, on the other hand, have lon been neglected in this respect. Over-voltage phenomen in low-voltage networks have only been investigated t a very limited extent, and lightning arresters have onl been used sporadically. One of the reasons for this i that the power companies do not have the same eco nomic interest in protecting the consumers' low-voltag installations as they have in protecting their own high voltage networks. It is the insurance companies, and, i the final instance, the consumers, who must mainly bea the economic losses arising as a result of these over voltages. Lack of knowledge as to the appropriate lo

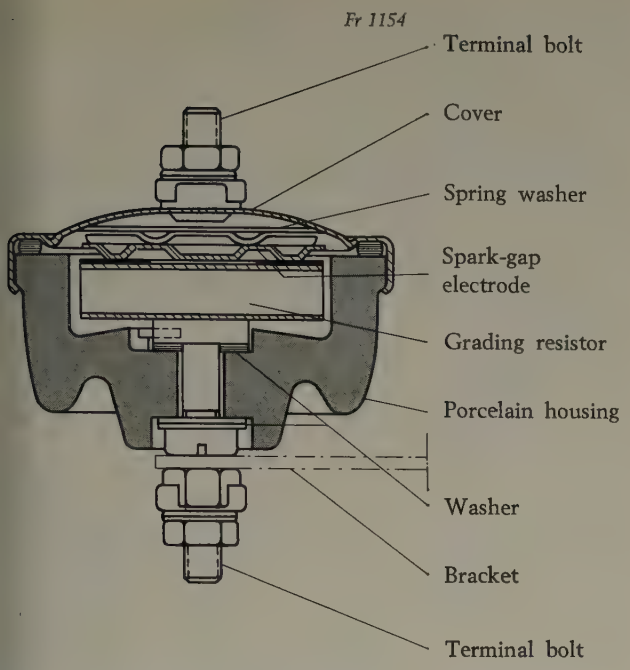

Fig. 1. Section through a lightning arrester of type XHA for low-voltage networks. The spark gap and the non-linear resistor are hermetically enclosed in a casing.

cating of the lightning arresters, and the extent of the protection which they can be expected to provide, have probably also contributed to the fact that low-voltage lightning arresters have not been more widely utilised. The problem of protecting low-voltage networks is of a special nature, depending on the particular earthing conditions and on the great variations in the surge strength of the installation. It has therefore not been possible to make use of the experience gained of over-voltage protection in high-voltage networks to any extent in the case of low-voltage networks.

Every year, over-voltages in low-voltage networks give rise to considerable economic losses as a result of fires and other damage to installations, and in many cases, they may also cause serious danger to persons. The blowing of fuses in domestic installations is a very usual occurrence during thunderstorms and is a considerable inconvenience to consumers. It is therefore particularly valuable that, in recent years, comprehensive investigations have been made in this sphere, which, to a very great extent, have revealed the nature of the over-voltages, the insulation strength of the low-voltage installations and the degree of protection provided by the lightning arresters.

In 1956, investigations were carried out in Danish low-voltage networks on the initiative of Danske Elværkers Forening and Foreningen af Gensidige Danske Brandforsikringsselskaber (The Danish Association of Electricity Supply Undertakings and The Danish Association of Mutual Fire Insurance Companies), with the co-operation of Asea [1]. Further, in 1958, a large number of low-voltage installations at Hindås near Gothenburg were investigated in collaboration with Hindås Elektriska Distributionsförening (The Hindås Electrical Distribution Association) and Svenska Elverksföreningen (The Swedish Association of Electricity Supply Undertakings) [2]. The two above-mentioned investigations have, amongst other things, provided reliable information as to the insulation strength of low-voltage installations in general.

In 1958, Sune Rusck published, in his Ph.D. thesis [3], a calculation of the induced over-voltages which can arise in low-voltage networks and a theoretical treatment of the protection problems connected with this. In the same year, Rusck published, in Asea Journal [4], some of the results he had arrived at in his investigations. The results obtained by Dr Rusck made it possible to calculate, in a simple way, the protective effect which can be expected from a lightning arrester.

THE ORIGIN OF OVER-VOLTAGES IN LOW-VOLTAGE NETWORKS

The most usual over-voltages in low-voltage networks can be divided up into over-voltages arising as a result of direct lightning strokes on the lines, induced over-voltages and transformed over-voltages.

Low-voltage overhead lines are usually suspended from wooden poles and the insulation level of the lines is therefore very high as compared with that of the installations. Consequently, practically all flashovers or punctures will occur in the installations and at the weakest points in these. If the installations are protected by lightning arresters, the over-voltage surge will be discharged by these, provided that the protective level of the arresters is lower than the insulation strength of the installation by an adequate amount.

In the case of direct lightning strokes on the lines, very high over-voltages arise which far exceed the insulation strength of the low-voltage installations. Rusck quotes the figure of approximately one direct stroke per 20 years per kilometre of overhead line as a representative figure for Swedish conditions [3], but, naturally, major local variations must be reckoned with. Thus, these phenomena are relatively rare.

By far the greater number of atmospheric over-voltages in low-voltage networks are induced over-voltages which arise when lightning strikes in the neighbourhood of the line or strikes between clouds. Over-voltages of this kind arise both in high-voltage networks and low-voltage ones. They are particularly harmful in the case of low-voltage networks since the induced over-voltages very often exceed the insulation strength of the low-voltage installation and, therefore, in unprotected installations may

lead to flashover or puncture with the consequent risk of fire. For a description of the mechanics of induced over-voltages, reference should be made to the work by Rusck mentioned above [3, 4].

In certain cases, over-voltages can be transmitted from a high-voltage network to a low-voltage one. According to current Swedish regulations, the neutral of the low-voltage side must not be connected to the earth terminal of the high-voltage side, unless the resistance of the earth terminal is so low that the voltage drop caused by the earth-fault current in the case of an earth fault on the high-voltage side keeps below a permitted maximum value. Favourable conditions of this kind are not often met with, and therefore, separate earthing is usual. When the lightning arresters on the high-voltage side operate, the current passing through them can often cause an increase in the earth potential, and this may lead to a flashover from the transformer tank to the low-voltage side, or what is known as backflash. However, the peak value of the over-voltages which can arise in this way will not exceed about 10 kV.

PLANNING OVER-VOLTAGE PROTECTION

Lightning arresters provide the best protection against over-voltages (Fig. 1). They consist of a spark gap which is connected in series with a non-linear resistor; these parts are enclosed in a hermetic casing. When the voltage across the arrester reaches the sparkover voltage of the latter, the spark gap strikes and the over-voltage is discharged to earth. The grading resistor has a non-linear voltage-current characteristic, and this means that the voltage across the arrester changes relatively little when the current through the arrester increases. Therefore, even in the case of high discharge currents, the voltage across the arrester is limited to a low value. After the discharge, the grading resistor limits the follow current from the network to such a low value that the spark gap is able to extinguish the arc.

The lightning arresters are connected between each phase and neutral, which, in accordance with the safety regulations in force in Sweden, must be earthed both at the transformer and at the periphery of the network.

When planning over-voltage protection, it must be borne in mind that the problem of protection on low-voltage networks differs in certain important features from the corresponding problem in high-voltage networks. Thus, it is required of lightning arresters for high voltage that they should be able to limit the over-voltages to a value which, under virtually all conditions, is lower than the insulation strength of the installations. For economic reasons, it would be unrealistic to place the same demands on the low-voltage arresters. Instead, the object is to reduce the number of occasions on which damage is caused to installations to a reasonably low value and, as far as possible, to prevent danger to persons during thunderstorms.

It should be possible to achieve almost 100 % protection of low-voltage installations if it were possible to arrange an earth terminal with very low resistance to which not only the lightning arresters and the neutral were connected, but also all conducting objects in the neighbourhood of the lines. In addition, the discharge voltage of the lightning arresters would have to be lower than the actual insulation strength of the installations, even in the case of the highest lightning impulses which could be expected to occur.

For practical and economic reasons it is usually difficult to arrange protection of this kind. For one thing, conducting objects in the neighbourhood of the lines are not always connected to the neutral. In the case of a discharge through a lightning arrester, the potential of the neutral is increased as a result of the voltage drop which the discharge current causes in the earth resistance of the neutral. Therefore, the entire electrical system may take on such a high voltage level that flashover occurs to other conducting objects. Thus, the arresters protect those parts of the installation which are connected between phase and neutral, but they cannot always prevent flashover between the electrical installation and earth.

Another factor which exerts an influence on the protective effect of the lightning arresters is the distance between the arresters and the installations which are to be protected. It would be too expensive to fit a set of lightning arresters at each installation, and the most usual course is therefore to erect the lightning arresters at certain strategic points in the network where they have to provide protection for a number of installations. However, the protective effect falls off as the distance between the arresters and the installation increases.

In the case of direct lightning strokes on a line, the current wave may amount to many thousands of amperes. The discharge current through the lightning arrester can then be so great that the voltage across the arrester combined with the voltage drop in the neutral exceeds the insulation strength of the installation. In cases such as this, there is also the risk that the surge may exceed the current strength of the lightning arrester, thus destroying it. Thus, in spite of the fact that, in the case of direct lightning strokes, the arresters can only in certain cases prevent flashover in the installations, and in spite of the fact that the highest discharge currents are a threat to the reliability of the lightning arresters, the latter ensure a reduction in the over-voltages to a fraction of their original values, and in this way greatly reduce the risks to persons and material damage.

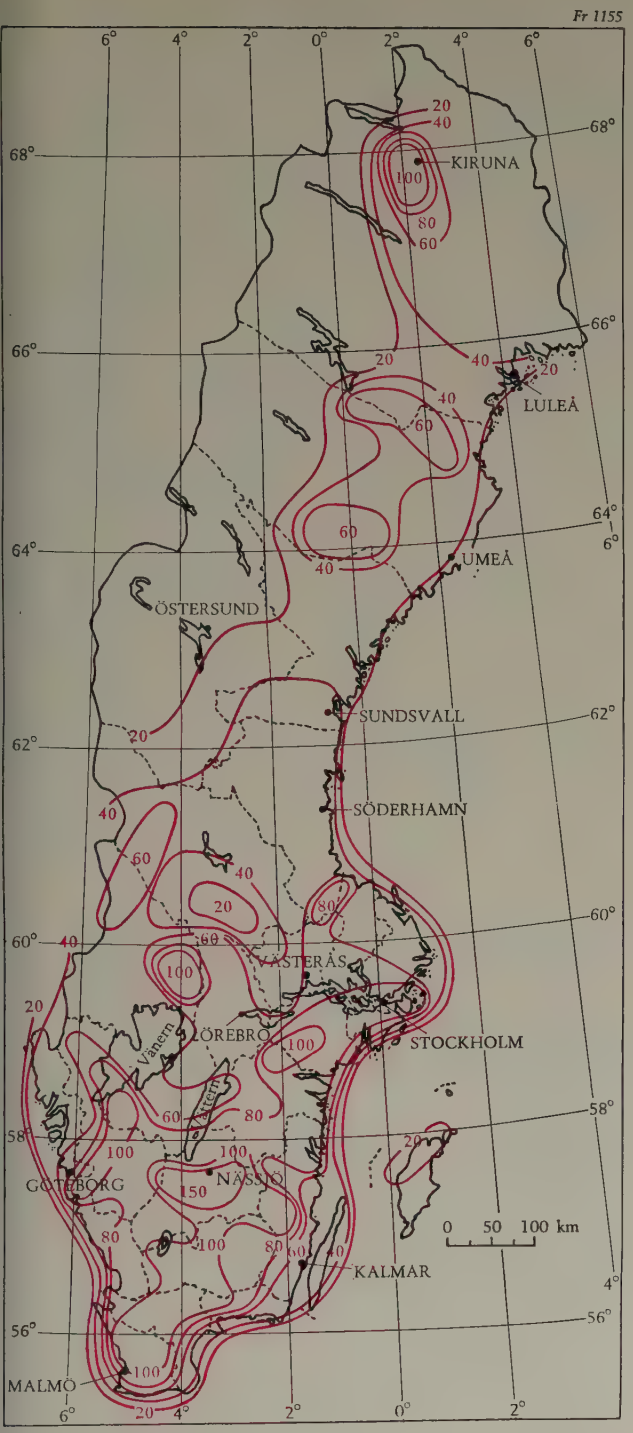

Fig. 2. Map of Sweden for the summers of 1958 and 1959 showing the number of lightning discharges registered per 100 km² per year.

THE PROTECTIVE EFFECT OF THE LIGHTNING ARRESTERS

What degree of protection can then be expected in a network which is equipped with lightning arresters? As mentioned above, the object of the lightning arresters is to reduce the number of over-voltages occurring in the installations, the peak value of which exceeds the surge strength of the installations. Thus, it is possible to obtain a measure of the protective effect of the lightning arresters by working out the relationship between the fault frequency with, and without, lightning arresters.

The number of faults per year in a low-voltage installation because of induced over-voltages mainly depends on the insulation strength of the installation, the distance between the lightning arresters and the installation, and the frequency of lightning strokes. The relation between these factors has been dealt with by Rusck [3, 4], who has shown that, at the values of the insulation strength and distance in question, the fault frequency is approximately inversely proportional to the square of the insulation strength of the installation and approximately directly proportional to the square of the distance between the lightning arresters and the installation.

An ordinary low-voltage installation should have a surge strength of at least 5 kV (peak value). In an installation of this kind in an area with two lightning strokes per square km per year, about 20 flashovers per year would occur if the installation were unprotected. If the installation were protected with the aid of a lightning arrester, which were mounted at a distance of 300 m, there would only be about one flashover per year, which is a considerable improvement.

On the basis of Rusck's investigations, it is possible to calculate how often the induced voltages in a low-voltage network exceed the insulation strength of the installation both in unprotected and protected networks, and thus assess the protective effect of the lightning arresters. Approximate values can be obtained by means of the expressions

$$N_1 = 20\,\frac{n}{2}\left(\frac{5}{U_{is}}\right)^2$$

$$N_2 = \frac{n}{2}\left(\frac{5}{U_{is}}\right)^2\left(\frac{d}{300}\right)^2$$

$$\frac{N_2}{N_1} = \frac{1}{20}\left(\frac{d}{300}\right)^2$$

where

N_1 = the number of times per year the induced over-voltages exceed the insulation strength of an installation in an unprotected network

N_2 = the number of times per year the induced over-voltages exceed the insulation strength of an installation in a protected network

n = the number of lightning discharges per km² per year

U_{is} = the insulation strength of the installation (5–10 kV peak value)

d = the distance between the lightning arresters and the installation in metres

Fig. 3. Surge device for checking the surge strength of low-voltage installations. (53607)

Lightning Committee No. 1 of the Swedish Academy of Engineering Science is making measurements of the frequency of lightning strokes throughout Sweden with the aid of lightning counters. The investigations, which are being carried out under the leadership of Professor D. Müller-Hillebrand at the High-voltage Research Institute at Upsala University, were started in 1958. The results of the measurements during the lightning period 1958 have been given in a report [5]. The map in Fig. 2, which was drawn on the basis of measurements made during the summers of 1958 and 1959, shows the number of lightning discharges registered per 100 km² per year. Naturally, these figures can vary a great deal from year to year, but the "lightning contours" indicate which areas are most threatened by atmospheric over-voltages.

OTHER MEASURES IN CONJUNCTION WITH OVER-VOLTAGE PROTECTION

The lightning arresters must be the main weapon in the battle against over-voltages. As has been shown in the previous section, a very good protective effect can be obtained with the aid of them. A condition for this is however that the surge strength of the installations should be higher than the protective level of the lightning arresters by an adequate amount. Otherwise, the protective effect of the lightning arresters will be illusory.

In conjunction with the investigations at Hindås previously mentioned, a surge device was designed which makes it possible to check the surge strength of the installation and to localise any possible faulty spots in a particularly simple way [2]. The device (Fig. 3) works with voltage surges which are introduced into the low-voltage installation about once a second, and the shap of which more or less corresponds to the shape of th induced over-voltages. The peak value of the surges ca be regulated in steps between a nominal 2.0 and 6.5 kV the voltage being however, to some extent, dependen on the capacitance of the installation which is bein tested.

The advantages of the surge device as compared with a ordinary insulation tester are twofold. For one thing, th surges bridge the small air gaps which are often foun in series with a fault point and which make an insulatio tester react as though the installation had no faults, an for another thing, the surges make a crackling sound a the fault each time they bridge it. The indicator of th device shows that there is a flashover somewhere in th installation and it is then merely a question of followin the faulty line until the sound is heard. This saves muc work when localising faults. It may also be mentione that the energy of the surges corresponds approximatel to those usual in electric fences. Because of the lo energy of the surges and the absence of follow current the surges do not introduce any risk of the formation o soot or any other successive deterioration of the instal lation. Surge devices of the above-mentioned type ar now being produced in considerable numbers.

Investigations made with the aid of the surge device hav proved that many installations are in a very poor state The most usual fault is careless wiring [2]. Most of th faults are of such a nature that they can be put righ easily and at low cost.

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THE PROBLEM OF NOISE IN ELECTRICAL MACHINES

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Asea Reg. 4174

Brief analysis of the causes of the noise emitted by rotating electrical machines. Some examples of the steps taken by Asea to reduce the noise of their machines. Methods of measurement adopted and their standardisation.

Electric motors are finding an ever wider application in the office and in the home for driving various machines. For such applications it is of the greatest importance that the machines should operate sufficiently silently so as not to cause discomfort. The solution of this problem often necessitates close co-operation between the customer and the supplier of the electrical machines.

Within industry too, growing emphasis has been placed on the silent running of machines in order to reduce the risk of injury to the auditory organs and to promote a sense of well-being among the personnel. Furthermore, this development has been accentuated by the advances in modern design practice itself. In order to achieve a low weight and price of their machines, the designers have often been forced to utilise more fully the materials at their disposal, by increasing the current loading and magnetic density and using larger amounts of cooling air. Furthermore, cast structures have been replaced in many cases by welded steel structures. Since the internal damping of steel is 50 to 1,000 times less than that of cast iron, there is a risk that these steel structures with low damping will give rise to pronounced resonance amplification. There is thus a greater risk that modern electrical machines may have a considerably higher sound pressure level than earlier designs. By appropriately avoiding any correlation between the power frequency and the resonance frequency, however, as well as by carefully designing the ventilation system, it is possible, nevertheless, to prevent the sound pressure level from being increased.

On the other hand, the need for silent running should not be exaggerated. If, for example, the driven machines themselves have a high sound pressure level, it is possible to permit the use of a noisier, and perhaps cheaper, electrical machine. In addition, when extreme quietness is required, it may be advantageous to use a standard motor mounted behind a screen or beneath a hood rather than to select a specially silent machine. The costs of such measures may often be considerably lower than the difference in price between a particularly quiet machine and a standard one.

Both in the office and in the home as well as within industry a certain amount of acoustic planning of the installation is thus essential. In this connection, it is important to know how the noise emitted by machines originates and how it affects the sound level in the room where the machine is located and in the neighbouring rooms.

In the following a general survey is given of the acoustical properties of electrical machines, partly illustrated by means of a few practical examples. In accordance with standard pratice [1], the strength of a sound is defined by its sound pressure level L_p, given in decibels (dB), and expressed by the equation

$$L_p = 20 \log \frac{p}{p_0}$$

where

p = actual pressure (r.m.s. value), in N/m²
p_0 = reference pressure = 2×10^{-5} N/m², which corresponds to the minimum audible (threshold) pressure for a pure sound at a frequency of 1,000 c/s.

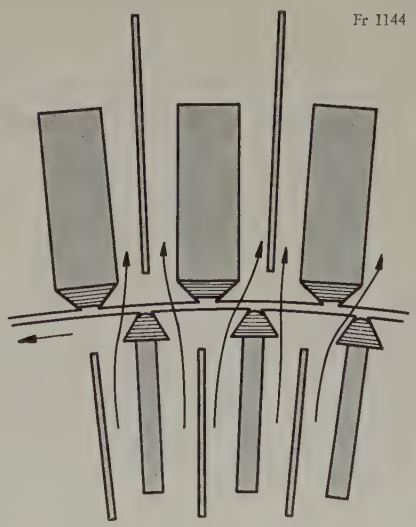


Fig. 1. Flow of air through the radial cooling ducts in an induction machine. The variations in the flow resistance result in pressure pulsations of both stator, and rotor, slot frequency.

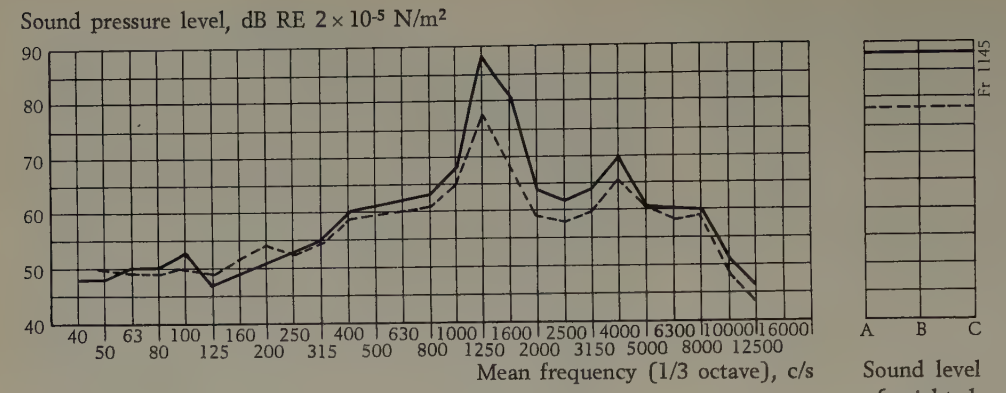


Fig. 2. Third octave analysis of the noise emitted by an induction motor rated at 300 kW, 970 r/m, of open design. The curve has a maximum value derived from the varying flow resistance in the radial cooling ducts, cf. Fig. 1. The broken curve shows the spectrum after the slot wedges have been machined 4 mm.

According to this definition of the sound pressure level, 0 dB corresponds to the threshold level at 1,000 c/s. A change in the sound pressure level of 1 to 2 dB is barely perceptible to the human ear, whereas an attenuation of 8 to 10 dB corresponds to a halving of the subjective response.

A more detailed description of the acoustic quantities is given in the literature [1] and in the Asea pamphlet 7728 E (The problem of noise in electrical machines).

COMPOSITION OF SOUND

The following parts of an electrical machine can generate sounds within the audible range of the human ear:

1. The ventilating system
2. The bearings
3. The brushes
4. The magnetic circuit

The predominant sound depends on the size, speed and enclosure of the machine and, to a very great extent, on its design. The sound emitted by the ventilating system is mainly airborne and is normally only troublesome in the premises where the machine is installed. Quite different is the situation with regard to the bearing and magnetic noise. This noise is derived normally from vibrations in the mechanical parts of the machine or from the entire machine itself, and the noise can thus be transmitted via the foundation, walls and any piping systems to other parts of the building, where it may cause inconveniences. This latter type of noise is called structure-borne noise. An effective way of avoiding such noises is to set up the machine on suitably dimensioned resilient mountings. In this connection, it might be pointed out that arbitrarily selected resilient mountings may lead to the amplification of these vibrations.

VENTILATION NOISE

The noise emitted by the ventilating system comprises normally two components, namely a noise having a line spectrum, with frequencies which, for example, may be a multiple of the number of fan impeller blades, and a white noise, i.e., a sound whose spectrum is continuous and uniform as a function of frequency over a sufficiently large frequency range [2].

Pure sounds with fan-blade frequency may arise, for example, due to a sort of siren effect, if the distance

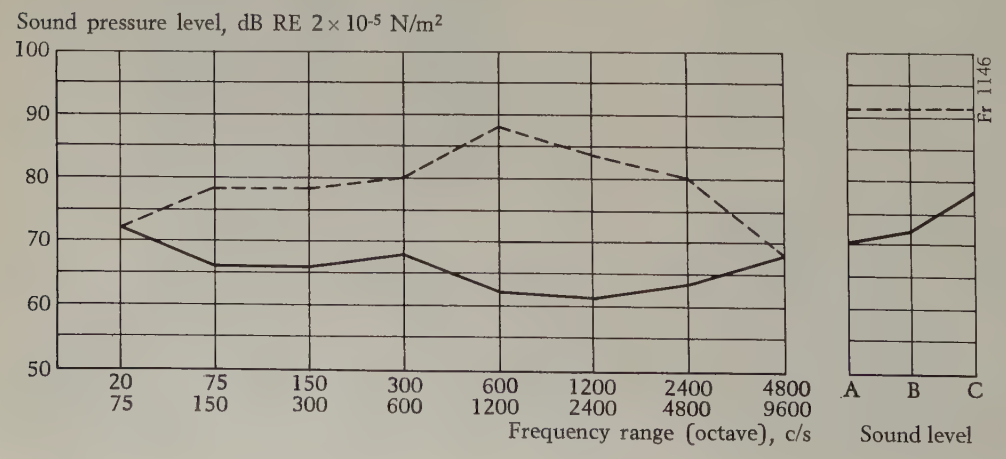
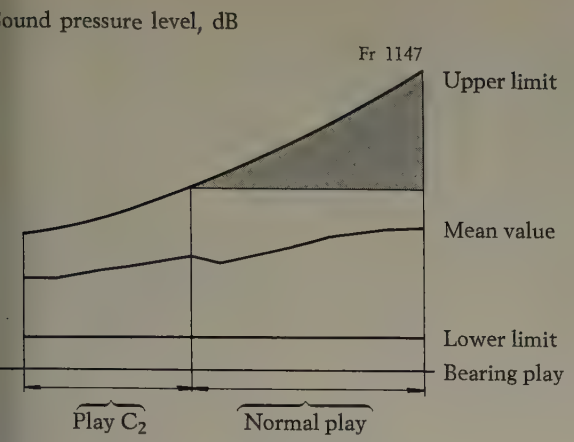


Fig. 3. Octave band analysis of the noise emitted by two frequency converters. The broken curve applies to a ventilated, enclosed converter, rated at 50 kVA, 983 c/s, 2,970 r/m; the full-drawn curve refers to a water-cooled converter, rated at 30 kVA, 973 c/s, 2,920 r/m



ig. 4. Sound pressure level as a function of the bearing play f 500 electric motors of 0.74 kW, 1,500 r/m.

etween the fan blades and rigid structural parts is too mall. This critical distance increases with the peripheral peed, and high-speed machines are therefore fitted vith smaller fans than those for slow-speed machines f the same type.

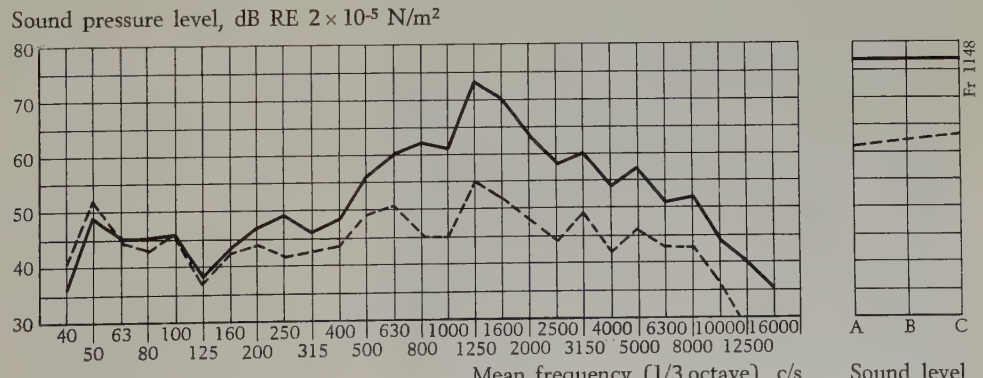
f a machine has radial cooling ducts, a siren effect nay also be experienced when the air from the cooling ucts passes the narrow air-gap between the slot wedges f the stator and the rotor. This is illustrated in Fig. 1, vhich shows that the flow resistance encountered in the assage of the air-gap is dependent on the angular po- ition of the rotor, resulting in pressure pulsations of both tator, and rotor, slot frequency. The sound pressure evel for the rotor-slot frequency is normally at least 5 to 20 dB higher than for the stator-slot frequency. As an example, Fig. 2 reproduces a third octave analysis f the noise emitted by a relatively high-speed induction notor of open design. The sound spectrum has a pro- nounced tone with the frequency 1,360 c/s, which in he third octave analysis appears as a peak for the band vith the mean frequency 1,250 c/s. In this connection t should be mentioned that a third octave band covers he frequency range from 0.89 to 1.12 times the mean requency.The band with the mean frequency 1,250 c/s, or example, covers the frequency range 1,110 to 1,400 /s. The sound pressure level at the stator-slot frequency vas in this case 15 dB lower than the sound pressure level at the rotor-slot frequency and thus of no importance.

In the case in question, machining of the slot wedges by 4 mm reduced the sound pressure level of the siren tone by 10 dB. In many cases, however, it is impossible by this means to reduce the sound pressure level by more than 2 to 4 dB, i.e., a barely perceptible improvement. Neither is it feasible to move the conductors further away from the air-gap without impairing the performance of the machine. Furthermore, at least as far as induction motors and commutator motors of this size are concerned, the ventilating ducts cannot be omitted because of the thermal utilisation of the machine. With high-speed medium-sized machines of open design it is thus impossible to avoid these siren tones, but they seldom constitute any problem with machines of ventilated, enclosed design.

As already mentioned, the flow of air through the fan as well as the inlet and outlet ventilation openings of the machine results in a white noise. For air velocities of up to 50 m/s the radiated acoustic power is proportional to the fifth power of the fan speed. The change in the sound pressure level ΔL_p as a function of the characteristic length l of the fan and the speed n is given by the equation

$$\Delta L_p = 70 \log \frac{l_2}{l_1} + 50 \log \frac{n_2}{n_1}$$

For peripheral speeds above 50 m/s the factor 60 or 70 should be adopted in the place of the factor 50 in the second term. From this it is apparent that an increase of 60 per cent in the speed results in an increase in the sound pressure level of at least 10 dB, corresponding to almost a doubling of the subjective response. If the sound pressure level is to be kept within reasonable limits, small fans must be used at high speeds. Another possibility is to arrange a closed cooling system either by means of direct cooling with water (see Fig. 3) or by means of a heat exchanger. A third possibility is to fit silencers on the inlet and outlet openings of the machine. If such silencers are to be of any use, they will generally be rather bulky [3].



ig. 5. Third octave analysis f the noise emitted by a hree-phase motor of 0.75 W, 1,400 r/m, which has een lubricated with two ifferent types of grease.

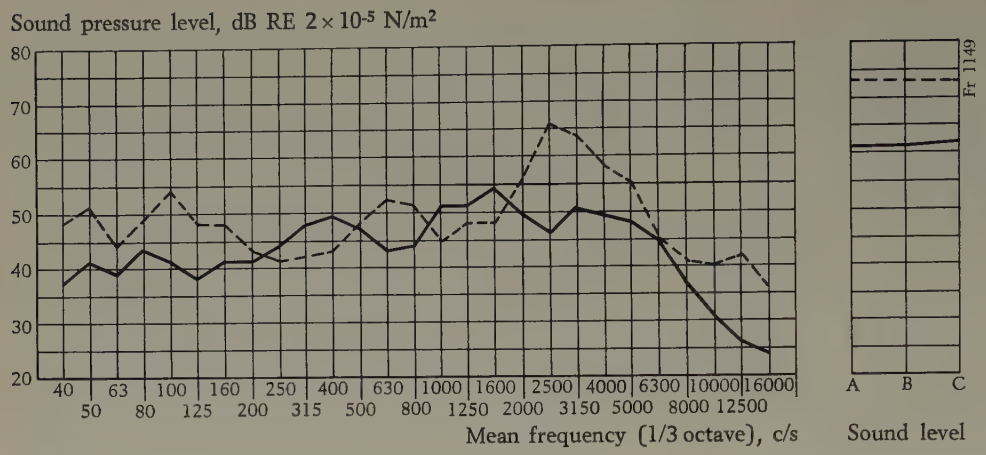
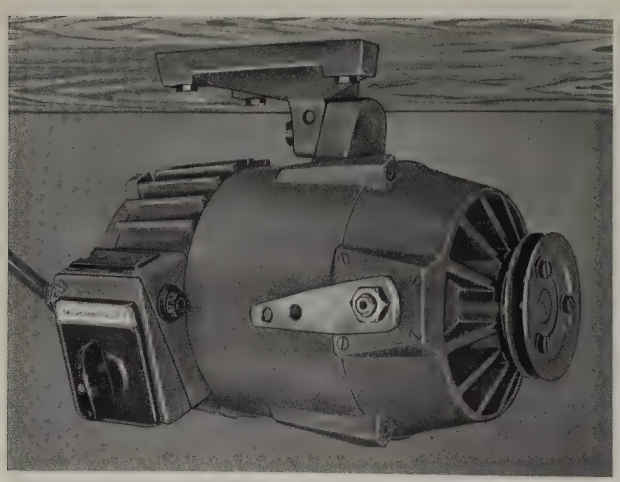


Fig. 6. Third octave analy of the noise emitted by motor for industrial sewi machines. Measuring dis- tance 30 cm. The brok curve refers to an older design, and the full-dra curve to the new desig

BEARING NOISE

The action of a bearing is based in principle either on rolling or sliding. Sleeve bearings are normally silent. The sliding motion in properly designed bearings results in only small forces, which are effectively damped by the oil film. On the other hand, the balls and rollers in even the most carefully made rolling bearings have a slightly differing size and surface finish, and this results in a series of small accelerations and retardations of the roller bodies and holders. Since the oil film between the rolling surfaces is normally very thin, no real damping effect is achieved on the contact surface. The stationary and rotating parts of the machine thus start oscillating and generate sound. The frequency spectrum of the sound depends greatly on the resonance conditions in the associated mechanical system (bearing end-shields, stator frame, fan blades, fan housings, etc.). The sound pressure level is related to a large extent to the internal damping of the material and the manufacturing accuracy of the bearings and the mechanical parts. The magnitude of the bearing play is of the greatest importance (Fig. 4), but the properties of the lubricant too ca exert considerable influence (Fig. 5).

Fig. 7. The new Asea motor for industrial sewing machines. (54883)

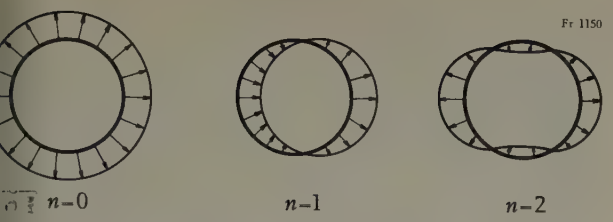


An example of the attenuation of the ball-bearing an ventilation noise is illustrated in Fig. 6, where the sour spectrum of an older type of motor for industrial sewi machines has been compared to that of a modern mot for the same purpose. The new motor (cf. Fig. 7 has an axial ventilating system, which leads to sever practical advantages.

BRUSH NOISE

Brush noise will arise if the brush or brush-holder forced to oscillate due to the eccentricity of the com mutator or if the brushes beat against the edges of th commutator segments. Such a noise may also occur the coefficient of friction varies along the periphery the commutator. In such cases a rigid coupling of th brush-holder arms can be very detrimental, since th oscillations of the individual arms are forced to be phase, thus magnifying the amplitude of the vibratio and consequently increasing the sound pressure leve By allowing the brush-holder arms to move indepen ently of one another, the resultant vibrations, and thu also the sound pressure level, may be lower.

The brush noise consists normally of pure sounds wit frequencies which are multiples of the segment fr quency. As a rule, this noise has consequently a rath high frequency, and it is propagated mainly from th brushes and the brush-holders themselves. It is tran mitted only to a very slight extent as a structure-born sound, and thus usually causes problems merely in th room where the machine is installed. The brush noise greatly reduced by enclosing the machine. Owing to th high frequency of the brush noise, the effectiveness the enclosure can be considerably increased by usi sound-absorbing material in those openings throug which the noise passes. However, careful designing the commutator and the avoidance of resonances in th brush system generally make such measures unnecessar



ig. 8. The simplest forms of oscillation which may occur the stator core laminations. The number of complete aves along the stator periphery is denoted n.

AGNETIC NOISE

Iagnetic noise arises when the mechanical parts of the achine, mainly the core laminations, are made to os-illate under the influence of the radial harmonic forces f the air-gap field. Such noise can occur in all electrical achines, but it is particularly difficult to master in in-uction machines. This type of machine will therefore e selected as an example.

he air-gap field in an induction motor with an infinite umber of phases and an infinite number of slots in both ie stator and the rotor and with the rotor exactly entered comprises only the fundamental wave. The oise emitted by such a machine would contain only ne tone of twice the network frequency and of low evel, which means that the machine would run practi-ally without emitting any noise.

normal electrical machine, however, has only three hases and a limited number of slots. The air-gap field onsequently contains an infinite number of harmonics f the form

$$_{\nu}=\hat{B}_{\nu}\cos(\nu x-\omega_{\nu}t-\varphi_{\nu})$$

here

$_{\nu}$ =the instantaneous value of the magnetic induction for the ν:th harmonic

$_{\nu}$ =the amplitude value of the magnetic induction for the ν:th harmonic

=the angle along the stator periphery, measured in mechanical degrees

ω_{ν} =the angular frequency

φ_{ν} =the phase angle

Both the stator and the rotor generate an infinite number of such field waves, which combine and form radial force waves of the form

$$f_n=\hat{F}_n\cos(nx-\omega_n t-\varphi_n)$$

where

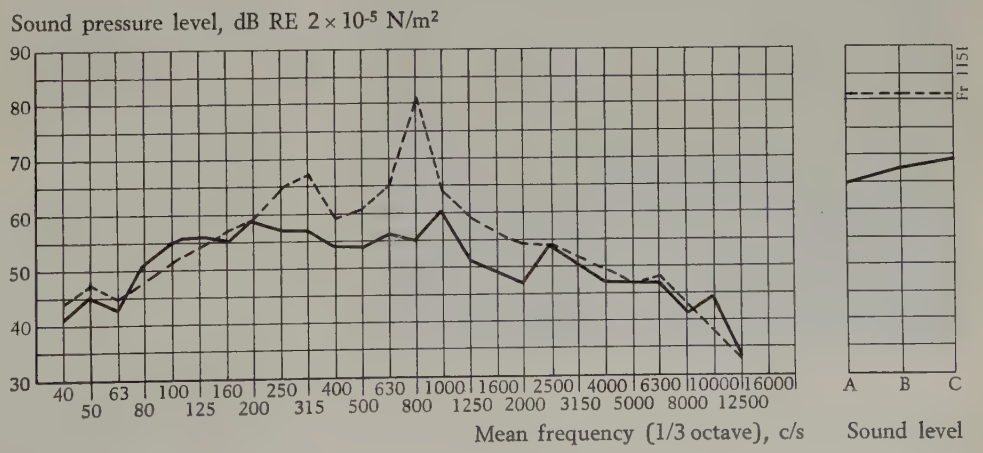
f_n =the instantaneous value of the force of the n:th order

$\hat{F}_n$ =the amplitude value of the force of the n:th order

If an unsuitable slot combination is selected, n may be small and ω large. The force then strives to make the core laminations oscillate either as a tube under alternating pressure, or with two, four or even more nodes. The simplest forms of these oscillations are depicted in Fig. 8.

The problem is most important for medium-sized motors, since their core laminations often have a four-node ($n=2$) resonance frequency of the four-node magnetic induction wave. By suitably selecting the number of slots and the mechanical dimensions, however, it is possible to prevent such undesirable mechanical resonance amplifications of the magnetic noise.

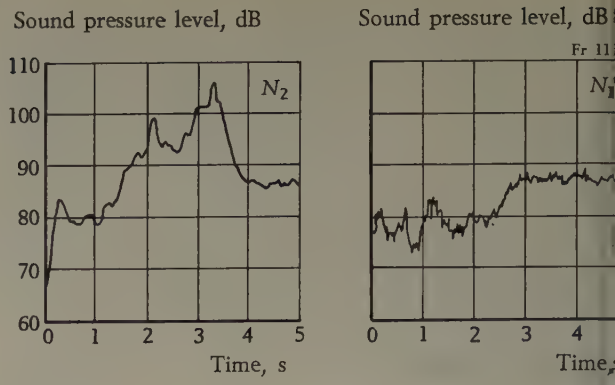
Fig. 9 shows as an example the third octave spectrum for a small converter comprising a d.c. generator and a squirrel-cage induction motor. The broken line denotes the sound pressure level for the original design. A pronounced peak can be detected within the band of mean frequency 800 c/s. This peak is derived from a magnetic tone of the frequency 830 c/s. It was possible to establish that this tone originated from the induction motor, the core laminations of which had four-node ($n=2$) resonance close to 800 c/s. By changing the number of rotor slots and the mechanical dimensions of the core laminations, the sound pressure level was reduced by over 20 dB within the band in question. At the same time, the ventilating system was modified by introducing various enclosures. This resulted in an at-



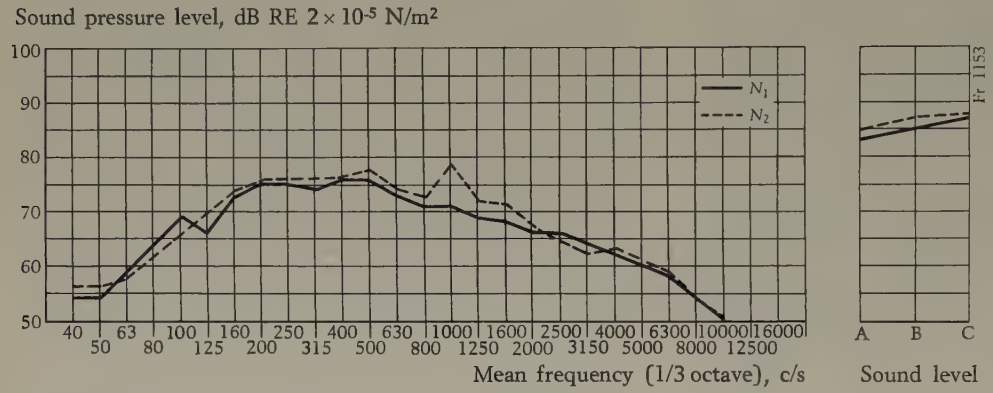
g. 9. Third octave analysis the noise emitted by a eonard converter rated at kW, intermittent duty, 440 r/m. The broken curve ows the sound pressure vel for the converter in original design, and the ll-drawn curve after anging the number of ro-r slots and modifying the ntilating system.

tenuation of the sound level of 8 to 10 dB within the bands of medium frequencies 250 and 315 c/s.

Also during starting, when the frequencies of the magnetic forces vary in proportion to the speed, an irritating noise can arise when the frequencies of forces with large amplitudes pass the resonance frequency. This phenomenon may cause most trouble in machines having a long starting time, and an example will therefore be given here of the sound abatement carried out on such a machine. The example refers to a Leonard converter for deck machinery comprising an induction motor and a dual generator [4–5].



a) Total sound pressure level during starting



b) Third octave analysis at rated speed

Fig. 10. Noise measuremen on a Leonard converter wi dual generator with two different numbers of slo N_1 and N_2, in the rotor the driving motor.

Such a converter has a relatively long starting time due to the large inertia of the dual generator, and it was established that a very irritating noise was generated during this period. This was all the more unfortunate, since such converters due to their limited space require-

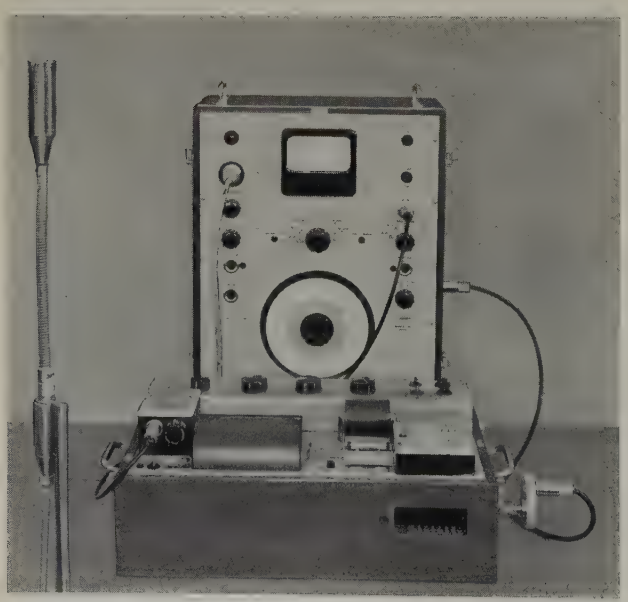


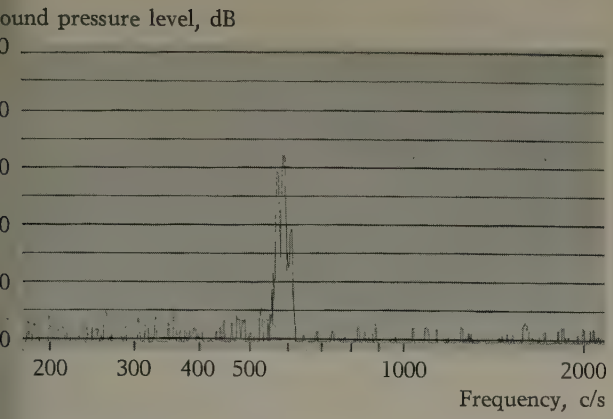
Fig. 11. Audio-frequency spectrometer and level recorder for third octave analyses (Brüel & Kjær). (Z 10057)

ments have often to be located in confined, alread existing compartments on board ship, sometimes in th vicinity of the crew's quarters.

By adopting a different number of slots (see Fig. 10 it was found possible in this case to reduce the max mum sound pressure level during the starting period b 20 dB. When the set is running at a constant speed, a improvement of 8 dB was experienced for those fr quencies lying within the mean-frequency band of 1,0 c/s. The sound level, on the other hand, does not displa any real difference, despite the fact that the convert had a more agreeable sound with the modified roto

NOISE MEASUREMENTS

As should be already apparent from this article, th problems associated with the noise emanating from ele trical machines are of a widely varying nature, an the ideal solution often presupposes knowledge fro widely differing fields. The numerous modern acou tical measuring instruments developed over the la decade constitute an indispensable aid in this researc The various spectrograms reproduced in this article order to illustrate the different cases constitute th mean values of several spectrograms recorded by a audio-frequency spectrometer (Fig. 11), which connec up in succession the third octave filters and registe



ig. 12. Frequency analysis of the noise emitted by a small nduction motor having a faulty air-gap, measured with wave nalyser having a constant band width of 2 c/s. (Z 11135)

he sound level. It is often essential, however, to perorm the analysis with still narrower bands in order to e able to establish the origin of the noise. An example f such an analysis is illustrated in Fig. 12. Three tones vith the frequencies 575, 592 and 609 c/s can be disinguished in the curve. A closer study of the harmonic ield of the motor shows that the sound with the frequency 592 c/s is derived from the eccentricity of the otor relative to the stator, whereas the sound of the ther two frequencies is due to the eccentricity of the otor relative to its shaft.

When making investigations of this nature, it is of the tmost importance that special acoustic test rooms are vailable, where the sound characteristics of the mahines can be studied without any interference from ackground noise. An example of such a room is deicted in Fig. 13. In order to achieve the lowest possible ackground noise, the room has been designed as an ndependent unit, set up on resilient mountings inside n independent building. This room was built in 1953, nainly for investigating the acoustical properties of mall machines.

When making research of this nature, each manuacturer may adopt his own methods of measurement. f, on the other hand, there is to be any chance of comaring two machines whose sound pressure levels have

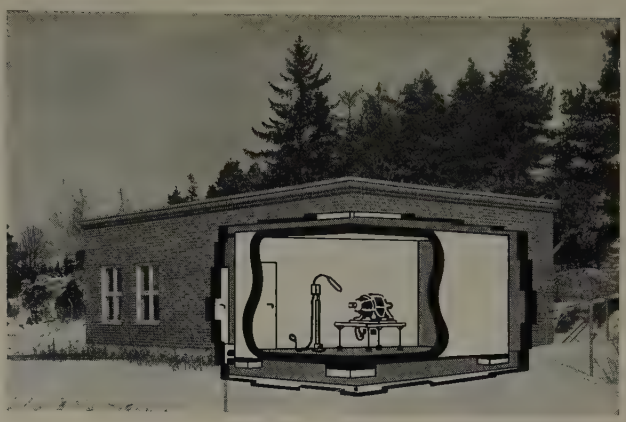


Fig. 13. The Asea test room for acoustic measurements on small motors. (Z 10054)

been measured in different places, a standardisation of the measuring procedure is vital. Particularly within acoustics, it is essential that the methods of measurement should be carefully specified, since the sound pressure level measured depends to a large extent both on the acoustical characteristics of the test room and on the distance of the microphone from the noise source. At the present time, however, great efforts are being made to lay down standards for noise measurements on electrical machines [6–9].

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20 MW STEAM TURBINE AT DETROIT

Asea Reg. 727

The official commissioning of the first steam turbine supplied by the De Laval Ljungström Turbine Co. to the U.S.A. took place on the 16th November, 1959, at Detroit. The customer was The Detroit Edison Co., which is a power-producing company with about 10,000 employees and an installed capacity of 3,761 MVA (in May, 1959) in its power-stations (exclusively thermal power apart from 7 MVA).

The turbine has been installed in The Beacon Street Heating Plant in Detroit, where it constitutes at present the largest set. It is a back-pressure turbine of double-rotation type with two air-cooled Asea generators having a total rating of 23.5 MVA at 4,800 V, 60 c/s. The rated speed is 3,600 r.p.m. and the power factor 0.85.

The delivery also included a transductor voltage regulator, a control desk with temperature supervisory equipment, automatic synchronising equipment, an electronic turbine governor as well as supervisory equipment for the turbine and generators.

The Detroit Edison Co. hat at its disposal its own laboratory where, for example, vibration investigations are made on models of the concrete foundations for the sets installed in the various power plants belonging to the Company. It has thus been possible to design the foundations so that no resonance will occur between the natural frequencies of the turbine and the foundations. This noteworthy care taken in the designing of the foundations together with the good balancing of the turbine ensures that the set will operate almost entirely free from vibrations.

(Z 1128)

TWO-CHAMBER INDUCTION FURNACES FOR THE MELTING AND HOLDING OF NON-FERROUS METALS

Karl Tiljander, Furnace Department, Västerås

U.D.C. 621.365.5
Asea Reg. 6642

Description of two-chamber mains-frequency furnaces for the simultaneous melting and holding of non-ferrous metals. Their long life, simple maintenance and low power consumption make these furnaces particularly valuable in foundries.

This new type of furnace, which, in practice, corresponds to two furnaces, permits both melting and holding to be performed simultaneously in the same furnace, which thus has a very wide field of application. The furnace is particularly useful in conjunction with the die-casting of aluminium and its alloys as well as brass, but may also be used with advantage for melting both ferrous and non-ferrous metals for mould casting.

As its name indicates, *the furnace comprises two chambers,* accommodated in a robust sheet-steel casing. The chambers are connected to one another by means of two melting ducts, between which the air-cooled furnace transformer is mounted. The charging material in the form of ingots or scrap is placed in the charging or melting chamber, while the molten metal is taken out with a ladle from the holding or casting chamber and transferred to the die-casting machine or mould. The temperature in the holding chamber is regulated automatically to the desired value, and, provided that the melting chamber is not charged too irregularly, a continuous supply of molten metal will always be available at the desired temperature.

In this way, it is possible to profit from two furnaces in one and to avoid the troublesome and costly transport of molten metal. If a two-chamber furnace is set up

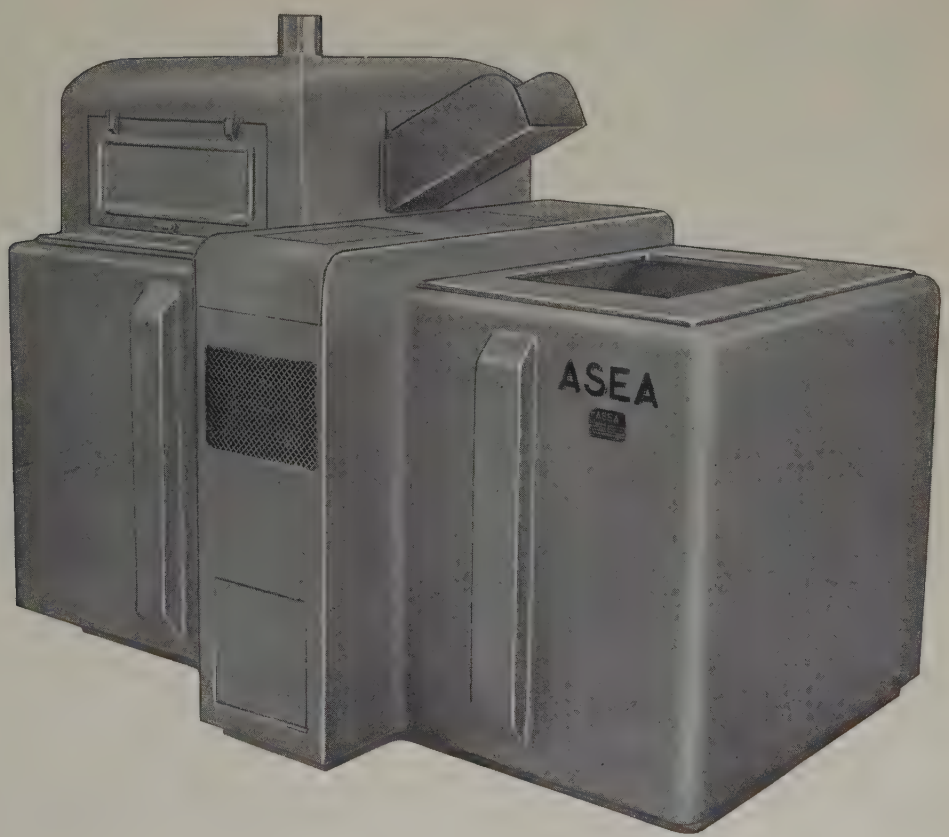

Fig. 1. Two-chamber mains-frequency furnace for melting and holding. The metal to be melted is charged through an opening in the hood over the melting chamber and molten metal of the correct temperature is always available in the holding chamber. (49669)

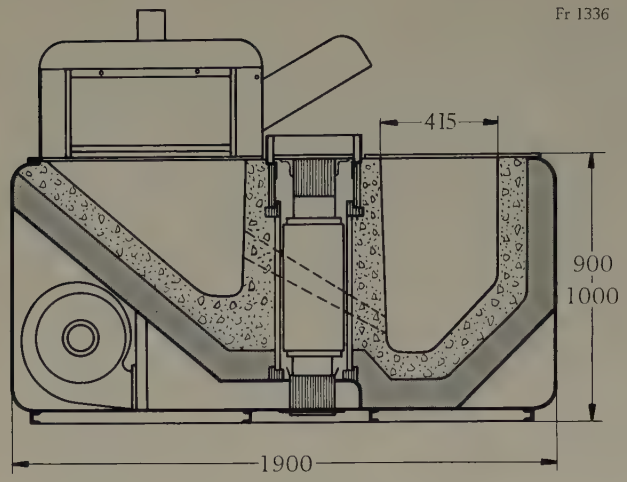

Fig. 2. Cross-section of two-chamber mains-frequency furnace for 40–60 kW.

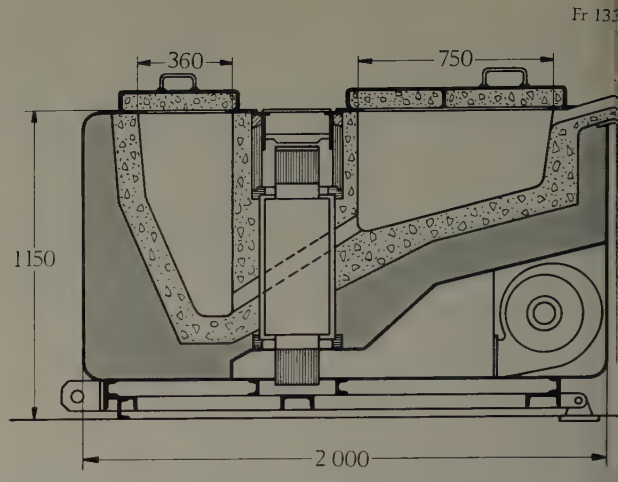

Fig. 3. Cross-section of two-chamber mains-frequency furna for 120–150 kW with tilting mechanism and pivots for rap tapping.

adjacent to each die-casting machine, all the difficulties involved in the transport of molten metal will be eliminated which would otherwise be the case with an individual melting furnace serving a number of holding furnaces.

As is apparent from the above, this type of furnace is intended to be tapped with the aid of a ladle, and it is thus a stationary unit. Since, however, it may be desirable in certain cases to be able to empty rapidly the furnace, it can also be fitted with a spout in the melting chamber (see Fig. 3). The furnace is then carried in a framework with pivots and is raised for tapping by means of a hoist, overhead crane or the like.

One of the advantages of this furnace type is that the bath movement in the melt ensures that an almost *pure surface* is obtained, since the greater part of the oxides and impurities will remain in the melting chamber. If the impurities should penetrate into the holding chamber due to the bath movement, they tend to accumulate on the inside of the bath surface, close to the centre of the furnace.

A two-chamber induction furnace is intended to operate continuously and to have a constant supply of molten metal in the melting and holding chambers. For this reason, a certain minimum amount of metal, the sump, must always be available in the furnace even when it is not in use, e.g., at night-time and over the week-ends. The no-load input is so low that it is not worth while shutting down the furnace and starting it up again. Naturally, the greatest economical gain is achieved if the furnace is utilised on two, or three, shift work.

When the furnace is not in use, the holding chamber should be fitted with a cover in order to save energy, and the temperature should be reduced to the lowest possible value, i.e., about 5°C above the melting temperature of the metal in question.

When the furnace is employed for *the melting of alu minium and its alloys,* the melting ducts should be regu larly cleaned if the furnace is to operate satisfactorily This is a very simple procedure to carry out, since th two-chamber furnace has straight ducts. Such a cleanin operation can be completed in fact within a few minutes

The furnace chambers are rammed in with a specia compound adapted to the metal which is to be melte in the furnace. A characteristic feature of this furnac type is the very long life of the lining, which has bee found by experience to be up to four years. Naturall it is possible to change the metal in the furnace, which however, must be completely tapped before chargin with a new sump.

A two-chamber furnace is relatively insensitive to dis turbances in the form of *service interruptions.* Th charge can be maintained molten for several hours, and should the metal solidify in the ducts, it is a simpl matter to heat it up again when the current returns. Th procedure to be adopted is clearly described in the oper ating instructions furnished with each furnace.

The appearance of the furnace is shown in Fig. 1. Th melting chamber is fitted with a sheet-steel hood, in corporating inspection openings and a sheet-steel spou for charging with scrap from the die-casting machine The furnace is equipped with a powerful built-in fa for cooling the inductor unit and the primary coil of th furnace transformer.

Provisions are made for the *automatic control of th temperature* in the holding chamber. The thermocoupl is protected by a tube of ceramic material having a hig mechanical strength with regard to the temperature an any corrosive effects of the melt.

The furnace transformer, which serves both chamber has a butt-jointed core and a primary coil for connection

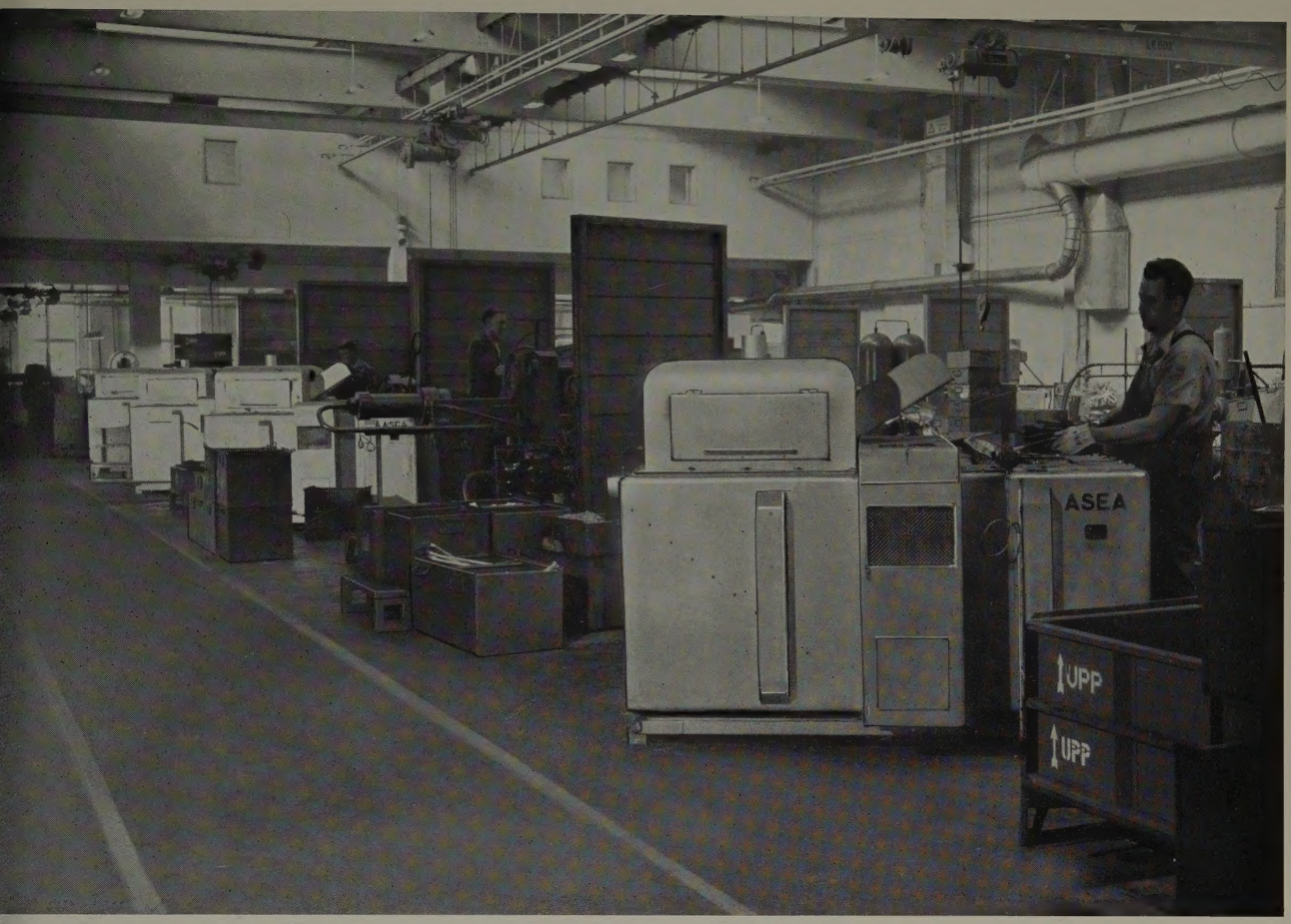

Fig. 4. Two-chamber mains-frequency furnaces installed in a die-casting foundry. Since one furnace is set up here by each die-casting machine, it is possible to eliminate all transport of molten metal. (55117)

to the supply network. The primary coil, which is simple to replace, is wound with copper having a square profile and insulated with glass-fibre tape, impregnated and specially treated to be able to withstand continuously a temperature of up to 400°C (750°F).

The furnace is designed so that it does not require any special foundation and it can thus be placed direct on the floor, even when it is fitted with the tilting arrangement described above.

Table 1. Standard sizes of two-chamber mains-frequency furnace.

Type	Furnace input	Effective charge	Sump weight	Total charge	Melting capacity	Energy consumption	Motor rating
	kW	kg	kg	kg	kg/h	kWh/t	kW
for aluminium					*at 700°C (1,300°F)*		
FR 83/40	40	230	220	450	75	535	0.5
FR 83/60	60	300	220	520	130	460	0.5
FR 96/150	150	460	460	920	360	410	1.0
for brass					*at 1,050°C (1,920°F)*		
FR 83/55	55	750	650	1,400	180	300	0.5
FR 96/150	150	1,500	1,500	3,000	440	340	1.0
for zinc					*at 500°C (930°F)*		
FR 83/40	40	700	670	1,370	310	130	0.5
FR 83/60	60	900	670	1,570	520	115	0.5
FR 96/150	120	1,400	1,340	2,740	1,100	110	1.0

A cross-section of a two-chamber mains-frequency furnace for 40–60 kW is shown in Fig. 2, and Fig. 3 illustrates the larger type for 120–150 kW.

The values given in Table 1 for the *melting capacity* and the *energy consumption* per ton of molten metal are the theoretical ones, and thus cannot be directly related to practical service conditions. In this respect, it is necessary to reckon upon a certain utilisation factor determined by the time required for charging of cold scrap, tapping, cleaning, etc. This factor is thus dependent on the time taken to carry out these various processes.

Each furnace is supplied with a thermocouple thermometer with associated compensating winding, an instrument and control-gear cubicle containing voltmeter, ammeter, kW-meter, kWh-meter, as well as all the necessary contactors, relays, fuses, signal lamps, etc. In addition, the furnace equipment includes a capacitor bank for improving the power factor of the furnace and, for the larger units, a holding transformer, which enables a lower holding input to be connected up during non-working hours.

Fig. 4 shows four two-chamber furnaces installed in a die-casting foundry.

NEWS IN BRIEF

S.S ORIANA EQUIPPED WITH ASEA DECK CRANES

On Saturday, December 3rd, 1960, the P & O – Orient liner S.S. Oriana of 41,923 tons gross, the largest passenger vessel to be built in the United Kingdom since the war, set forth on her maiden voyage to Australia.

The S.S. Oriana, which was built by Vickers-Armstrong at Barrow-in-Furness, possesses many unique design features and in several respects presents a revolutionary departure from traditional practice. Thus, for example, some of the leading British industrial designers were consulted at an early stage in the planning of the vessel. The clean and modern lines of the S.S. Oriana have been enhanced by the fact that the conventional derricks and samson posts have been completely eliminated, being replaced by deck cranes, eight in number, supplied by Asea through Fuller Electric Ltd., London, to the shipyard.

These 5-ton deck cranes each have a maximum slewing radius of 47 ft 6 in. and a minimum slewing radius of 14 ft 9 in. They are controlled by means of the Ward-Leonard system incorporating a triple converter, and all three crane movements, namely luffing, slewing and hoisting, are regulated by two simple controllers. An enclosed cab of glass-fibre-reinforced plastic gives the crane driver an excellent view over the scene of operation. Glass-fibre-reinforced plastic is also used for enclosing the crane machineries. Six of the deck cranes are of fixed type, and the remaining two on the foredeck are designed for travelling athwartships on a special turntable system of rails, thus permitting them to operate on either the starboard or port side of the vessel.

The aerial photograph taken of the S.S. Oriana while on her trials clearly shows how the clean lines of the Asea deck cranes harmonise with the impressive silhouette of the vessel. In addition, it might also be pointed out that the deck cranes have a great practical advantage in comparison with winches in that the handling of the cargo and passengers' luggage is greatly speeded up.

Asea Reg. 6344

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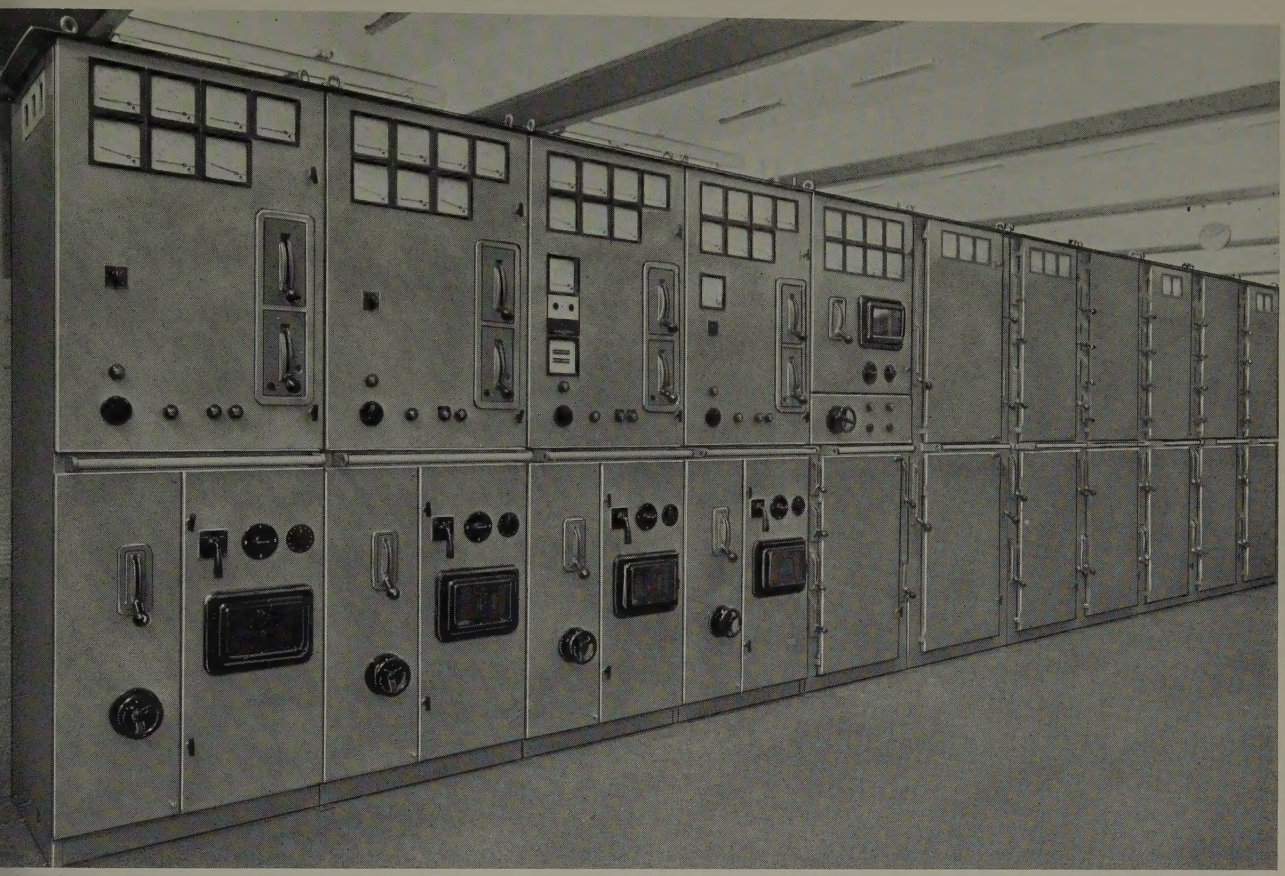


(54832)

IAIN SWITCHBOARD FOR FRUIT ARRIER

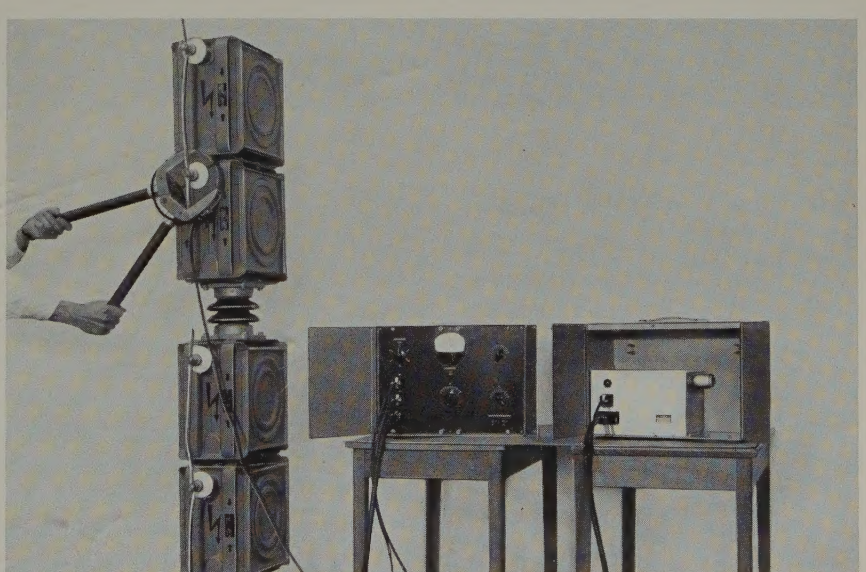
he illustration shows the main switch-oard for the m/s Hidlefjord a fruit carrier uilt at A/S Akers Mek. Verksted, Oslo, r Rederi Kornelius Ohlsen. The vessel of 600 tons d.w. is mainly intended for the ansport of fruit in refrigerated holds. urrent is supplied by four Asea generators, each rated at 310 kVA, 450 V, 60 c/s. An Asea emergency generator of 41 kVA, 450 V, 60 c/s has also been installed. The main switchboard has in all eleven panels, four for the main generator switchgear, voltage regulators, etc., one panel for the switchgear for the emergency generator, and six panels incorporating knife switches and fuses for the outgoing groups. An identical switchboard has recently been installed on board the m/s Byfjord built by the same shipyard for the same shipowner.

Asea Reg. 6220

ONGTEST INSTRUMENT FOR EASURING CAPACITANCE

ne illustration shows a tongtest instru-ent for measuring the capacitance in ch unit of a capacitor bank without being necessary to disconnect the leads tween parallel units. The instrument connected to 110 or 220 V, a.c. and e instrument readings are not affected harmonics or variations in the supply ltage, or by the presence of stray fields losses in the capacitor bank.

Asea Reg. 0962



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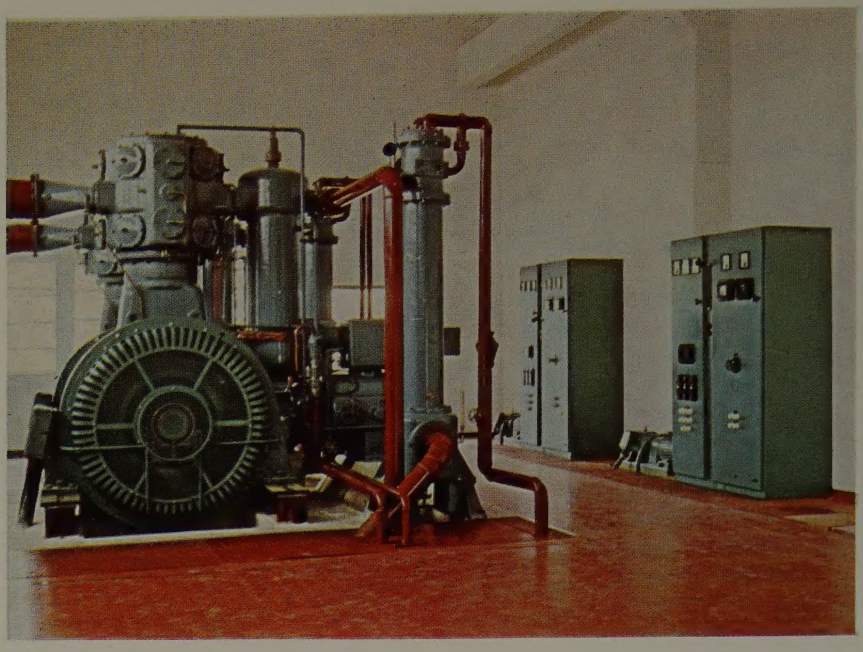

(F 656)

COMPRESSOR PLANT AT THE WORKS OF GENERAL MOTORS DO BRASIL

The illustration shows a compressor plant in an assembly factory for lorries, belonging to General Motors do Brasil, at S. José dos Campos in the State of São Paulo. In its initial stage this factory occupies an area of 60,000 m² on a site of 1,700,000 m².

The electrical equipment for the two Atlas-Copco compressors has been supplied by Asea and comprises two synchronous motors, each rated at 275 kW, 360 r/m, 440 V, together with their associated exciters of 4.5 kW, 110 V. Asea Reg. 4423, 833

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